Daily Ref #9

THE TRANSBOUNDARY AIR TOXICS STUDY

FINAL SUMMARY REPORT

DECEMBER 1990

Submitted to:

Pamela Blakley
Air and Radiation Division
USEPA Region V
230 S. Dearborn Street
Chicago, Illinois 60604

Submitted by:

Engineering-Science, Inc.
Two Flint Hill
10521 Rosehaven Street
Fairfax, Virginia 22030

ES ENGINEERING-SCIENCE

THE TRANSBOUNDARY AIR TOXICS STUDY

FINAL SUMMARY REPORT

(Work Assignment No. 47,
Contract No. 68-02-4398)

DECEMBER 1990

Submitted to:

Pamela Blakley
Air and Radiation Division
USEPA Region V
230 S. Dearborn Street
Chicago, Illinois 60604

Submitted by:

Engineering-Science, Inc.
Two Flint Hill
10521 Rosehaven Street
Fairfax, Virginia 22030

TABLE OF CONTENTS

ACKNOWLEDGMENTS

Engineering-Science (ES) would like to acknowledge the contributions of Federal, state, provincial, regional, and local agencies without whom this study would not have been possible. The original funding for this work was provided by EPA's Great Lakes National Program Office (GLNPO) through the Air and Radiation Division of Region V, with supplementary funding from the Air Pollution Control Division of the Wayne County (Michigan) Health Department, and GLNPO. Funding was also provided by the Michigan Department of Natural Resources to support the development of gridded mobile source emission calculation input data by the Southeastern Michigan Council of Governments.

Many helpful suggestions and comments have been supplied throughout this study. Among the agencies which have participated in this process are:

- Environment Canada
- Michigan Department of Natural Resources
- Ontario Ministry of Environment
- Southeast Michigan County of Governments
- Wayne County (Michigan) Health Department, Air Pollution Control Division

In particular, ES would like to note the contributions of EPA Region V's Air and Radiation Division, including Pamela Blakley (EPA's Technical Representative), Carlton T. Nash, and John Summerhays. In addition, ES would like to acknowledge the work of J. Jacob Vind who produced the PIPQUIC graphics and "pie" charts at various places in this report; preliminary work on these graphics was done through American Management Systems, Inc. This work was done under subcontract to ES.

Finally, ES would like to acknowledge the role of USEPA Region V's Southeast Chicago toxics study. While the results discussed in this document are the work of ES, some parts of this document have been taken in their entirety from V's final Southeast

Chicago report.[•] In this new study, ES has used the basic approach utilized by EPA for risk assessment, including standard assumptions (e.g., 70-year exposures, etc.). In this sense, this new study closely parallels the Southeast Chicago study, and this report therefore includes appropriate language from the Southeast Chicago report on risk assessment and how results should be interpreted. Emissions estimate and modeling methodologies are somewhat different (though similar) to those used by Region V, and these new methodologies are presented in this report.

[•] Summerhays, John, "Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southeast Chicago, "U.S. Environmental Protection Agency Region V, Chicago, Illinois, 1989.

DISCLAIMER

This summary report has been furnished to the U.S. Environmental Protection Agency in fulfillment of Work Assignment No. 47, Contract No. 68-02-4398. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the U.S. Environmental Protection Agency. Similarly, mention of company or product names should not be considered as an endorsement either by the U.S. Environmental Protection Agency or by Engineering-Science, Inc.

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Increasing national attention has focused on the health risks from "toxic" (non-criteria) air pollutants that arise in urban areas where a concentrated level of industrial activity coexists with high population density. Within EPA Region V is Southeast Michigan, an area that combines concentrated industrial activity with high population density. In particular, Southeast Michigan is one of the nation's foremost locations for motor vehicle manufacturing and a wide range of other manufacturing activity. Immediately across the United States/Canada border, the urbanized areas in and around Windsor and Sarnia, Ontario, also have high population density and a variety of manufacturing facilities.

AIR TOXICS AND THE GREAT LAKES

This combined area is also significant because it is located in or near the Great Lakes watershed. The quality of the environment in and around the Great Lakes has been a concern for some time. Originally, concern was focused on water quality degradation due to point sources, especially sewage disposal. In addition, the addition of nutrients to the lakes, such as phosphorus, encouraged algal growth and oxygen depletion. In the last decade, efforts to control these phenomena have met with some success.

While nutrient levels are gradually being controlled, thus reducing the threat of eutrophication, input of toxic substances to the Great Lakes continues to be of concern because of the potential impacts on human health. In addition, research has shown a variety of adverse ecosystem effects resulting from toxic substances. Accordingly, the sources, transport and fate of toxic substances in the Great Lakes, has become a major focus of many studies.

Early studies emphasized the dispersal and bioconcentration of organochlorine pesticides (such as DDT) and polychlorinated biphenyls (PCBs) through the ecosystems of

the Great Lakes. PCBs for example were found in lake water on Isle Royale in Lake Superior in the 1970s. Gradually, the ambient atmosphere has been determined to be a substantial source of toxic substances through both wet and dry deposition. As an atmospheric phenomenon, deposition's contribution to lake or soil concentrations of toxic substances have been known for some time (see for example Abbott et al, 1965). During the 1980's, public awareness of the phenomenon in the Great Lakes environment has increased, as reflected in coverage by periodicals and the mass media (see, for example, Botts, 1983, and New York Times, 1987). Special attention has been focused on the levels of toxic substances in Great Lakes fish, and the issuance of public health fish consumption advisories (USEPA/GLNPO 1988a).

For many substances, it is apparent that atmospheric deposition is the dominant pathway, particulary in the Upper Lakes away from major urbanized areas. Mass balance analyses have been performed which support this conclusion (Strachan and Eisenreich, 1988). For example, the atmosphere is considered to be a substantial contributor to the loadings of PCBs, DDT, lead, and benzo(a)pyrene. Estimates of lead and benzo(a)pyrene range from 46 to 97 percent and 72 to 96 percent, respectively.

DEVELOPMENT OF AIR TOXICS STUDIES IN REGION V, USEPA

Previous studies assessed and quantified the impacts of air toxics into the Great Lakes by focusing on air quality monitoring data in conjunction with mass balance techniques. With the purpose of further understanding the influence of the air toxics inputs to the Great Lakes, Region V's Air and Radiation Division, in conjunction with the Great Lakes National Program Office, directed Engineering-Science to conduct two studies: the Lake Michigan Air Toxics Emissions Inventory and the Transboundary Air Toxics Study.

The Lake Michigan study was designed to generate air toxics emissions inventories for the Consolidated Metropolitan Statistical Areas bordering Lake Michigan. This data base is planned for use in deposition modeling by USEPA. At about the same time, the Transboundary Air Toxics Study was initiated to prepare an air toxics emissions inventory for Southeast Michigan/Windsor-Sarnia area, which then was to be used in a two-part deposition and risk modeling analysis. It is the purpose of this report to present the results of this analysis. This study serves the purpose of evaluating the source types and pollutants which contribute to increased cancer risk from air pollution in the Southeast

Michigan/Windsor-Sarnia area, as well as estimating deposition rates in the area. Throughout this study, this area is referred to as the Transboundary area, or region.

This study may be considered in the context of national concern about urban air toxics risks. A USEPA report entitled The Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants (dated May 1985) estimates that as many as 1800 to 2400 cancer cases per year may be attributed nationally to air pollution (not including indoor radon) (USEPA/OAR and OPPE, 1985). This report further finds that while individual industrial sources may lead to high localized risks, a substantial share of the cumulative risk from air toxics comes from activities that are more population-oriented, such as driving motor vehicles. In fact, limited monitoring data in some large cities indicates that risks even in residential and commercial areas approach the risks found near the highest risk industrial facilities. Further, various studies suggest that cancer risks from air pollution throughout urban areas are commonly in the range of $1x10^{-3}$ (i.e., 1 case per thousand people exposed for a lifetime) to $1x10^{-4}$ (1 case in 10,000). These risks arise from the multiple sources of emissions of multiple pollutants that exist in all urban areas. Since 61% of the United States population lives in urbanized areas, and the exposure to high urban toxics risks extends throughout these urban areas, this urban air toxics exposure appears to contribute the major share of the cases of cancer attributable to air pollution. One of the purposes of this study, then, given the general national picture of urban air toxics risks, is to define, in more detail, the relative contributions of various source types to these risks in the Transboundary area.

CHAPTER 2

STUDY DESIGN

As indicated in Chapter 1, the Transboundary Air Toxics Study includes an evaluation of both deposition and human health risk. Given the historical interest and activities in both the United States and Canada in the study of toxic substances in the Great Lakes environment, and the important role of urban areas as sources of toxic substances, an urbanized area spanning the United States/Canada border is an ideal area for an air toxics case study. The Transboundary region, including both Detroit, Michigan and Windsor, Ontario, is such an area, with a population of approximately 4,285,000 (including nearly 499,000 on the Canadian side of the border), and a mix of industrial and other urban sources.

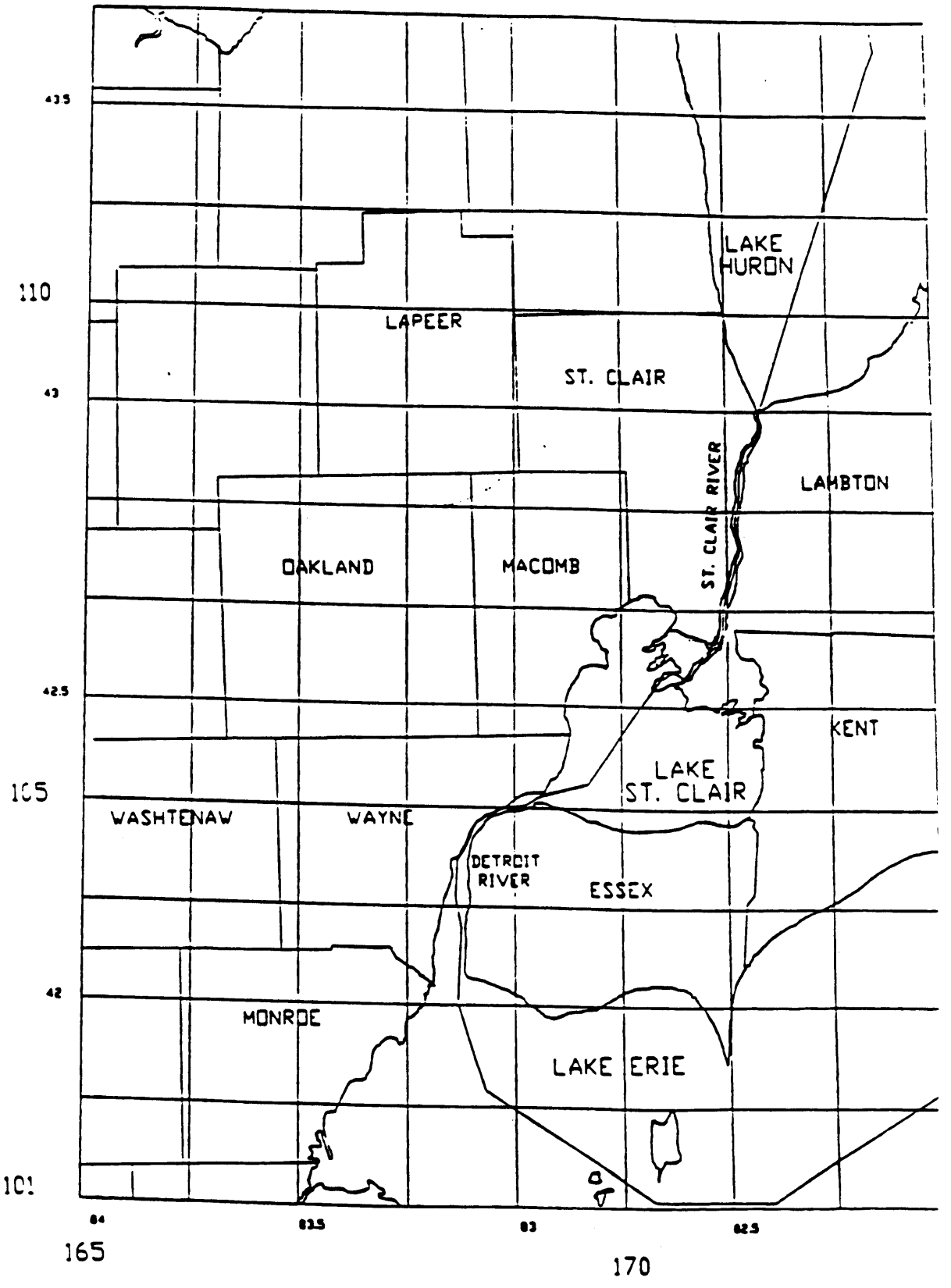
Prior to development of the databases to be used in the generation of emissions, the counties, pollutants, and source categories to be included in the inventory were chosen. In each case, priorities were established based on the relative importance of a county, pollutant, or source category to deposition and human health risk in the Transboundary region.

GEOGRAPHIC COVERAGE

As mentioned above, industrialized urban areas can produce substantial air toxics emissions. Accordingly, for this study, it was decided to focus on counties which include the industrialized areas within the Transboundary region*. A total of ten counties were chosen - seven in Michigan (Lapeer, St. Clair, Oakland, Macomb, Washtenaw, Wayne, and Monroe), and three in Ontario (Lambton, Kent and Essex). Figure 2-1 shows all of these counties along with an overlaid master grid with cells 20 km on a side. These grid cells are the same as those developed for the National Acid Precipitation Assessment Program (NAPAP) inventory. Utilizing the NAPAP grid provided a number of advantages,

*The study area was limited to roughly 50 km from Lake St. Clair and the Detroit and St.Clair Rivers due to the types of the modeling techniques planned.

Figure 2-1
Overlay of NAPAP Master Grid
On Transboundary Counties



including direct utilization of NAPAP VOC and TSP area source emission estimates, and consistent data on both sides of the international border. In order to provide further detail to the inventory, these cells were subdivided into quarters, so that each cell was 10 km on a side. and then further subdivided to 5 km and 2 1/2 km grids. Figure 2-2 shows the full area source grid and Figure 2-3 shows an enlargement of 2 1/2 km grid. Cell numbers in these figures designate the numbers used to designate and track grid cells throughout the study. All allocation procedures, as described in Chapter 3, were then organized according to this grid design. The receptor grid for modeling is the same as the source grid, except for extra receptors on a 2 1/2 km grid in the Port Huron/Sarnia area; the modeling approach is also discussed in Chapter 3.

POLLUTANTS

There are literally hundreds or even thousands of pollutants which could be included in a study such as this one. However, several criteria were utilized for help in choosing the pollutants to cover. As indicated above, both deposition analysis and risk assessment are potential applications of the final emissions data; as a result, the pollutants chosen were generally substances known to be atmospherically deposited into the Transboundary region, substances known to pose a carcinogenic risk or other substantial human health risk, or both. In many cases, emission sources of such pollutants have also been studied extensively by USEPA, thereby providing the basis for making emission calculations relatively efficient by using calculation factors on large databases.

A total of 57 substances was eventually chosen; a list is provided in Table 2-1. These pollutants may be broken down into seven categories:

- chlorinated solvents
- "common" VOC
- metals
- organics associated with chemical production and other chemical reactions
- pesticides
- polycyclic aromatic hydrocarbons (PAHs) and other products of incomplete combustion
- specialty and miscellaneous substances

Figure 2-2
Grid Cells for the Transboundary Area

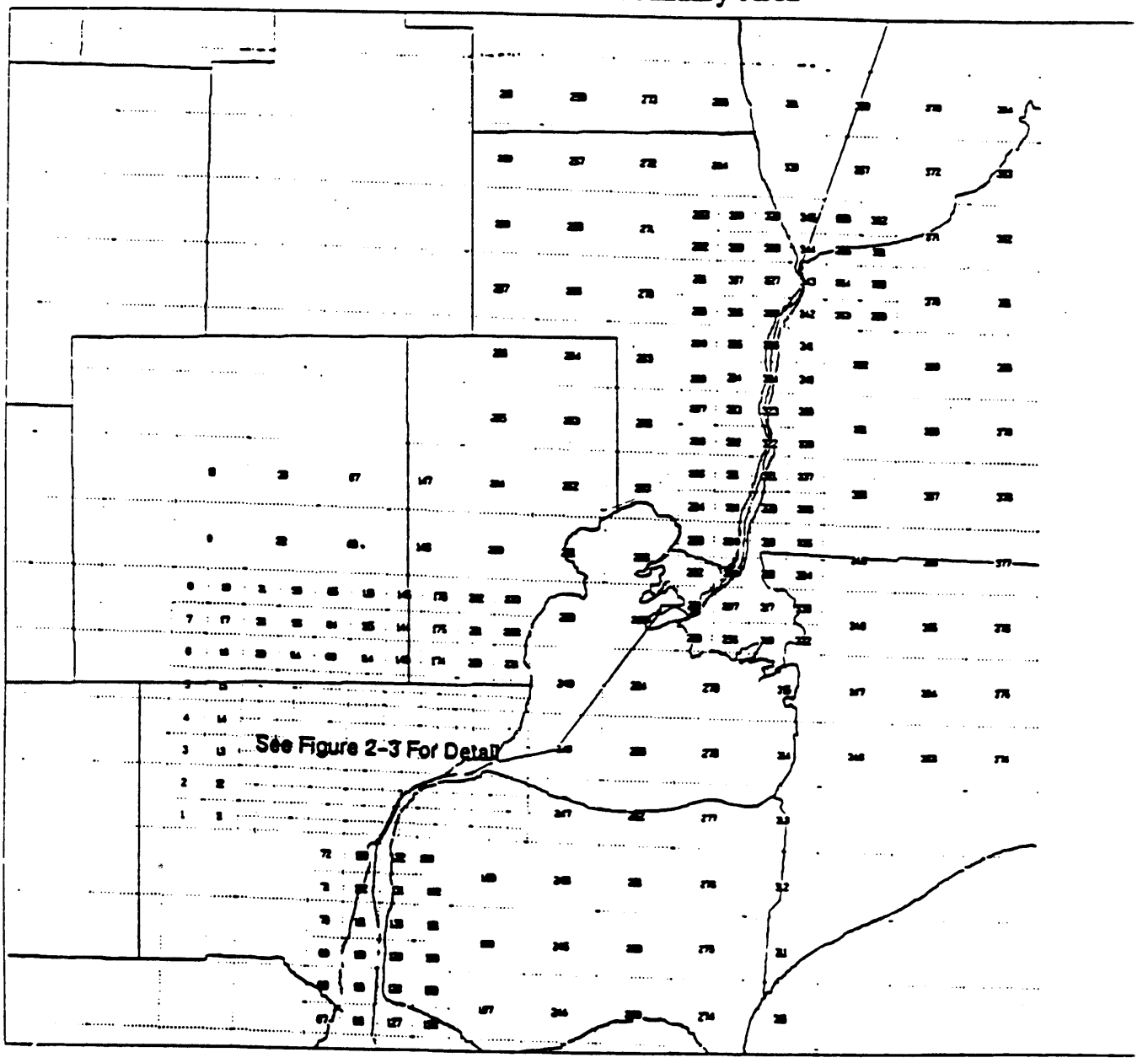


Figure 2-3
2.5 x 2.5 km Grid for the Core Area

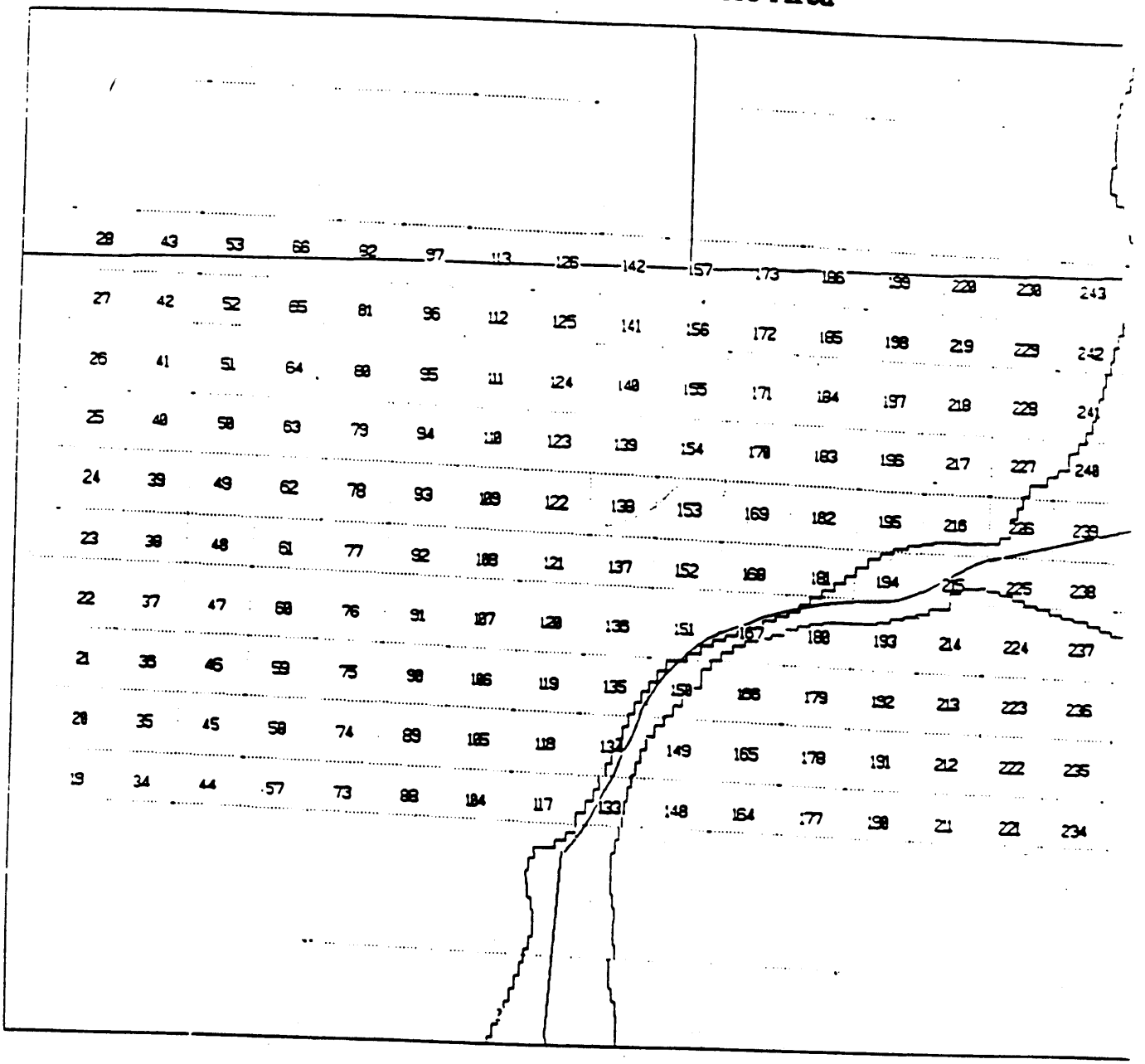


TABLE 2-1

SUMMARY OF POLLUTANTS BY TYPE

Type	Pollutant
1. Chlorinated Solvents	Methylene chloride
	Perchloroethylene
	Trichloroethylene
2. "Common" VOC	Benzene
	1,3 butadiene
	Carbon tetrachloride
	Chloroform
	Formaldehyde
	Gasoline vapors
3. Metals	Arsenic
	Beryllium
	Cadmium
	Chromium
	Lead
	Mercury
	Nickel
	Selenium
4. Organics/ Chemical Production and Reactions	Acrylamide
	Acrylonitrile
	Allyl chloride
	Di-n-butylphthalate
	Di-n-octylphthalate
	Epichlorohydrin
	Ethyl acrylate
	Ethylene dibromide
	Ethylene dichloride
	Hexachlorobenzene
	Hexachlorobutadiene
	Hexachloroethane
	Melamine
	Methyl chloride
	Octochlorostyrene
	Styrene
	Vinyl chloride
	Vinylidene chloride

TABLE 2-1 (cont'd)

SUMMARY OF POLLUTANTS
BY TYPE*

Type	Pollutant
5. Pesticides	Aldrin Chlordane Diazinon Guthion Heptachlor Heptachlor epoxide Parathion
6. Polycyclic aromatic hydrocarbons and other products of imcomplete combustion	Benzo(a)pyrene Chlorinated dibenzofurans Chlorinated dioxins Coke oven emissions Chrysene Dibenzen(a, h)anthracene Fluoranthene Methyl-benzanthracenes Methyl-chrysenes Phenanthrene Total PAHs
7. Specialty and miscellaneous substances	Asbestos Ethylene oxide Hydrogen sulfide Polychlorinated biphenyls

*Some pollutants are not of one type exclusively.

Based on the type of sources which produce these sources (combustion sources can produce metals and PAHs for example), a list of point and area source categories was then developed.

SOURCE CATEGORIES

A summary of [redacted] is provided as Table 2-2, and is broken down by point sources and area sources. It should be pointed out that this list [redacted] of the 57 substances; rather, it was [redacted], while limiting databases to a manageable size.

The facility and source data used as the initial database was the VOC and TSP emission inventory for the ten counties (seven in Michigan and three in Ontario) from the National Acid Precipitation Assessment Program (NAPAP). Supplemental data was used where available, including the databases of EPA (including the NESHAPs database), the Michigan Department of Natural Resources, the Ontario Ministry of Environment, and the Wayne County Department of Health (Air Pollution Control Division). Chapter 3 describes the general procedures used on this and other databases to develop emission estimates for the 57 substances, as well as the modeling approach employed. Chapter 4 presents the results of both the emission estimates and the risk assessment, while Chapter 5 presents the methodologies and results of the deposition assessment.

TABLE 2-2

SUMMARY OF SOURCE CATEGORIES

Point Sources
Chemical production
Coke and charcoal combustion
Coke ovens/iron and steel
Fuel combustion
Metals production
Motor vehicle manufacturing
Refineries
Waste incineration
Area Sources
Additional miscellaneous NAPAP categories
Architectural coatings
Auto refinishing
Cold degreasing
Cooling towers
Dry cleaning
Gasoline marketing
Mobile sources
Pesticides
Residential oil combustion
Residential wood combustion

CHAPTER 3

STUDY METHODOLOGIES

As indicated in Chapter 2, the Transboundary Air Toxics Study is based on 57 specific pollutants for a number of specific source categories. This chapter provides an overview of the methodologies used for both estimation of emissions and dispersion modeling. Specific methodologies used for the deposition assessment are discussed in Chapter 5.

INTRODUCTION

In order for dispersion and deposition modeling to be performed, emission inventory data, release parameter information (including stack data), and meteorological data is necessary. A risk assessment is then based on the ambient concentrations, the population known to be present in the area of the ambient concentrations, and the relative carcinogenic potential (as expressed by unit risk factors) of individual pollutants. The purpose of this chapter is to present the methodologies utilized to produce emission estimates, modeling estimates, and risk calculations generated in this study. Figure 3-1 presents a graphic overview of these methodologies.

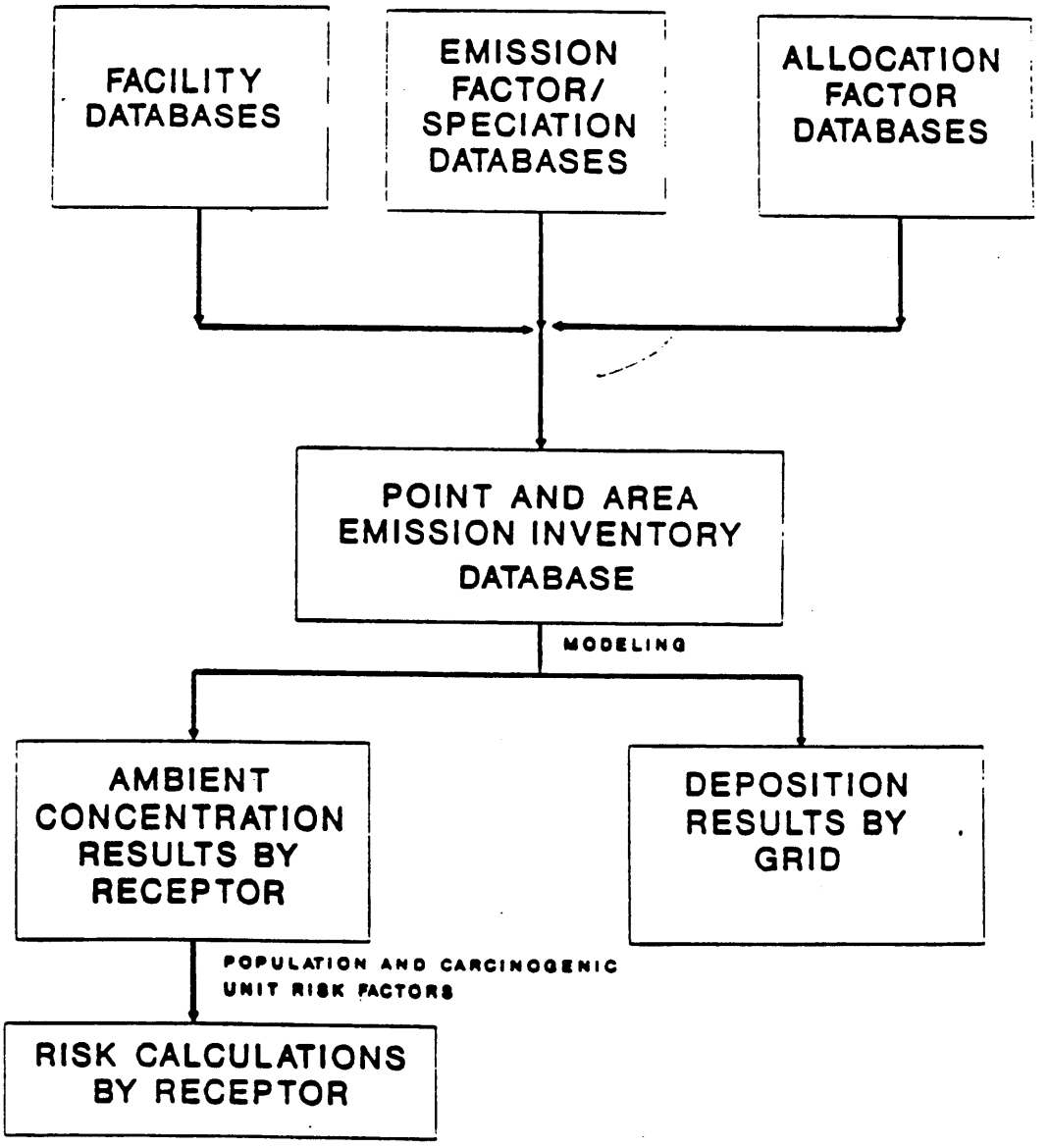
EMISSION ESTIMATES

Given the size of and the number of facilities in the Transboundary area, utilization of computerized databases and calculation techniques was essential. Large, programmed, computerized calculations of emissions allow for estimates for thousands of sources, and provides the basis for prioritization of quality assurance activities. Such estimates are usually based on use of one of three types of "indirect" calculation factors:

- air toxics emission factors;
- VOC speciation factors (species emission equal to a fraction of total VOC emissions); and

FIGURE 3-1

OVERVIEW OF EMISSION ESTIMATION AND MODELING METHODLOGIES



- particulate composition factors (substance emission equal to a fraction of TSP emissions).

Throughout this report, these factors are referred to as "primary calculation factors" (PCFs).[1] This section is focused on providing an overview of emission inventory methodologies used in this project.

Point Source Approach

There were two main types of databases -- facility/source data and PCF/emissions-related data. The primary facility/source data was [redacted]em (NEDS) database for the affected counties; this data was identical to the 1985 NAPAP data. Utilization of a processed PCF file (see below) on the NEDS/NAPAP file was the primary mechanism for estimating emissions. The overall organization of this data preparation and processing effort for point source data in this project is presented in Figure 3-2. (Additional evaluation of stack parameters was necessary before modeling could proceed; see section on dispersion modeling approach below.)

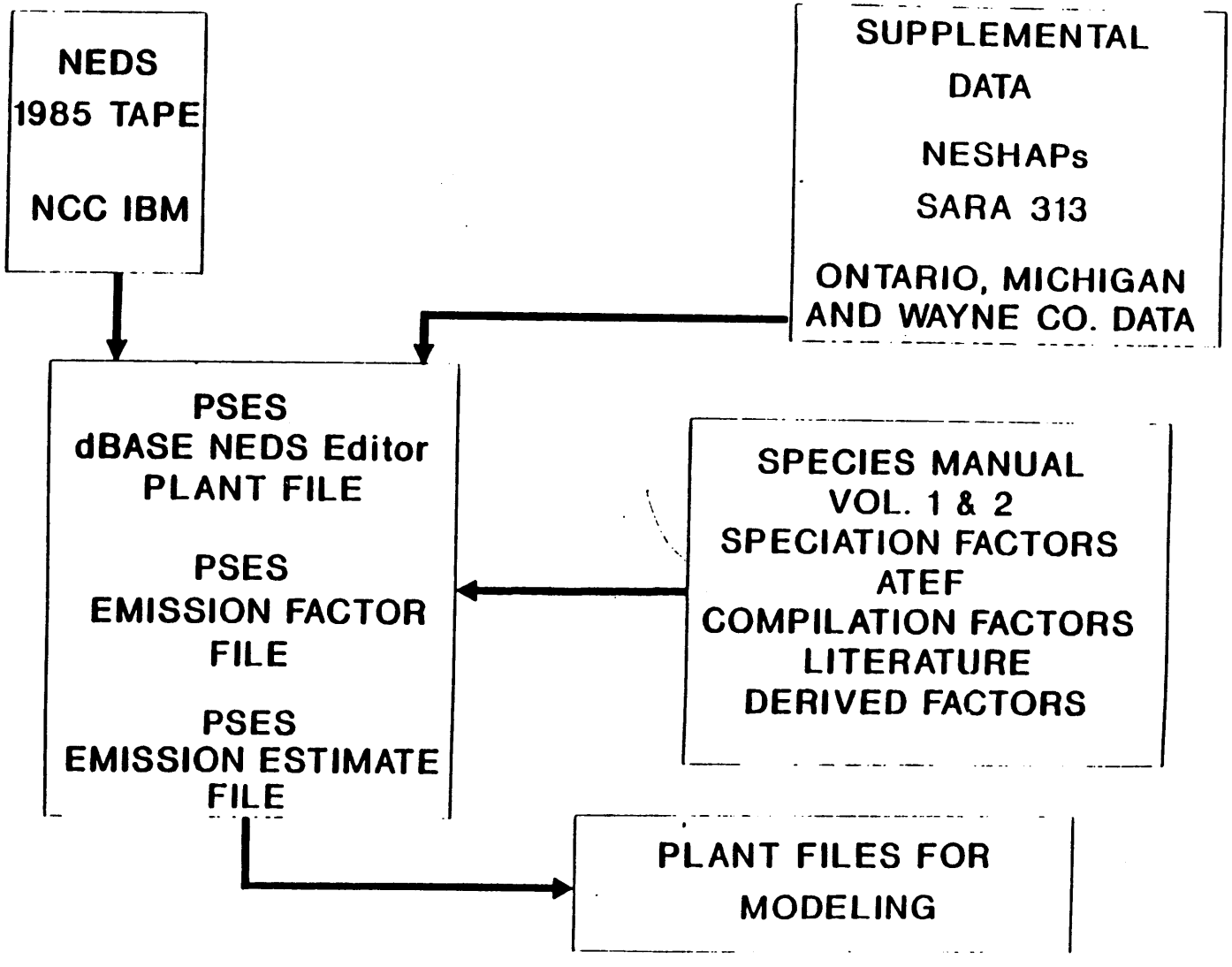
The NEDS/NAPAP data was chosen because it is relatively comprehensive, and was subject to a high level of quality assurance. These point source estimates combined with the NAPAP area source estimates represent total emissions of criteria pollutants. For example, industrial boilers too small to be listed as NAPAP point sources were included as area sources in the NAPAP area source deck. The combined NEDS/NAPAP point source and area source deck should therefore provide a fairly complete representation of traditional point source emissions based on criteria pollutants. The major effort to supplement this deck was geared at identifying special source categories which produce pollutants relevant to this study (see Chapter 2).

The database was supplemented by NESHAPs facilities listed in EPA's NESHAPs database as emitting the study-specific pollutants, and by the State of Michigan's point source files. As the NESHAPs database is facility-based (not based on emission points like NEDS) these sources were located in the databases and point-specific information was

[1] In all cases, polycyclic organic matter (POM) emission factors were used to estimate emissions of polynuclear aromatic hydrocarbons (PAH).

FIGURE 3-2

TRANSBOUNDARY POINT SOURCE DATA FLOW



obtained. Michigan's files provided a number of sources which were documented in neither the NEDS/NAPAP nor the NESHAPs database.

NEDS information was downloaded from EPA's NCC IBM in an 80 column format. This format allowed for direct uploading into PSES (the PC-based point source system used). Special source categories and NESHAPs facilities were then identified in the Michigan point source database (obtained in dBASE format), and these records were then converted to PSES records and appended to the NEDS point source files. Finally, an extensive literature review was conducted to identify emissions rates and speciation data where possible for all substances on the list.

While NESHAPs data was pollutant-specific, NEDS/NAPAP data [illegible] volatile organic compound (VOC) and total suspended particulate (TSP) emission information (plus other criteria pollutant information). Therefore, it was necessary to either speciate VOC and TSP emissions using [illegible], or to utilize specific air toxics emission factors. Speciation factors were available through computerized files of EPA's "Air Emissions Species Manual," which is available in two volumes, one for VOC (USEPA/OAQPS, 1988a) and one for particulate matter (USEPA/OAQPS, 1988b). Air toxics emission factors were available from USEPA's "Toxic Air Pollutant Emission Factors" (USEPA/OAQPS, 1988c).

Each of these volumes is extensive, and all are based on Source Classification Codes (SCCs). Many individual SCCs have multiple entries in EPA's "Toxic Air Pollution Emission Factors," and there is significant overlap between this document (SCC by SCC) and the "Air Emissions Species Manual." There was thus a need to provide a basis for determining what species fraction or what emission factor for individual pollutants should be used on NEDS/NAPAP data. (Species fractions are multiplied by VOC or TSP emissions, and toxic emission factors are multiplied by appropriate activity parameters, such as units of input, etc.) A protocol was therefore developed to evaluate and prioritize PCFs. Results then were evaluated for anomalies, and appropriate adjustments to the point source emissions were made.

Area Source Approach

The area source deck was developed to be consistent with the point source estimates. The NAPAP VOC/TSP estimates for point sources (NEDS facilities) and

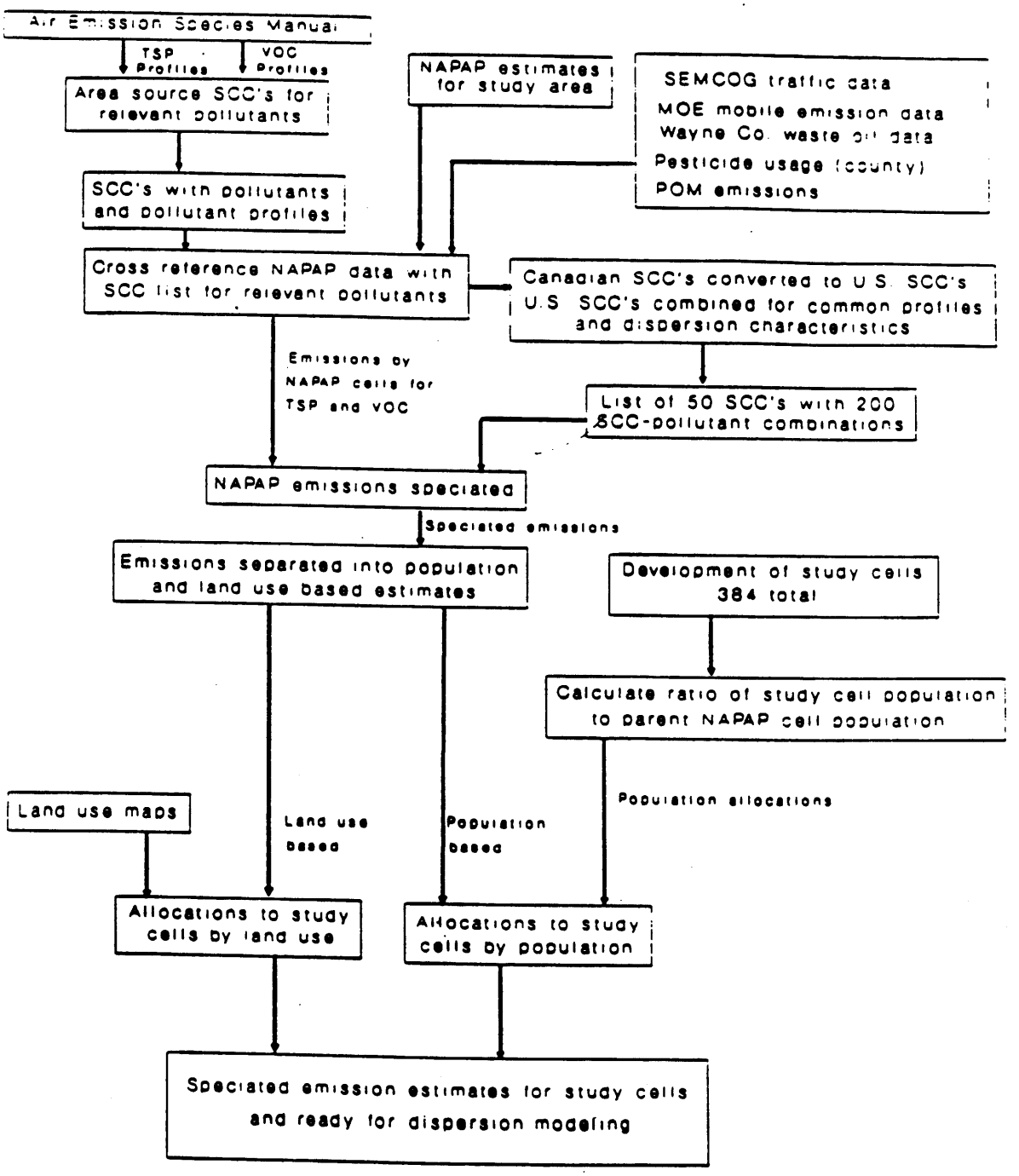
NAPAP area source VOC /TSP estimates combine to provide estimated total nationwide emission estimates. The matched deck concept has been described in the point source section with the idea that facilities too small to be found in the NEDS deck are compiled as small sources in the area source deck. The NAPAP area source deck further includes three-digit SCCs for mobile sources, residential combustion, forest fires and a wide variety of other sources of air pollution. The following discussion presents how these databases plus other databases were used to generate area source emission estimates. Figure 3-3 provides a flow chart detailing this process.

Data Sources and Emission Speciation – Several primary references provided the bulk of the data used in the development of the area emissions database. As with point sources, the primary source of the emissions data was the 1985 NAPAP emissions inventory. As discussed above, this inventory provided emissions for volatile organic compounds (VOC) and total suspended particles (TSP) from area sources for cells 20 km x 20 km in size (four times the size of the study cells). Therefore, it was necessary to speciate the NAPAP emissions for the toxic pollutants, and allocate these emissions to the smaller study cells. The Air Emission Species Manual provided emissions profile data, source category by source category. Unlike the point source approach, speciation profiles for all industry averages (00000) were used, but only for appropriate miscellaneous source categories.

A search of VOC and TSP speciation factors was conducted through dBASE to extract all profiles that produced any of the 57 study pollutants. These profiles were then matched to area source SCCs. A list of 85 area source SCCs was produced which resulted in emissions of the 57 pollutants. Because many of the SCCs were described by the same profile (light duty gasoline vehicles and gasoline trucks), some SCCs were combined and the SCC list was reduced to 44. VOC and TSP emission estimates were then obtained for the NAPAP cells (approximately 20 km x 20 km) in the study areas. Toxic estimates were then created for these 44 SCCs by pollutant for the NAPAP cells, according to the appropriate SCC profile.

Population Allocation Procedures – For the generation of the area dispersion modeling inputs, the study area was segregated into 384 cells (see Chapter 2). These cells range from 10 km x 10 km (1/4 of a NAPAP cell), down to 5 km x 5 km and 2 1/2 km x 2 1/2 km. The area emissions from each of the NAPAP cells are unique, but it was necessary

FIGURE 3-3
TRANSBOUNDARY AREA SOURCE DATA FLOW



to determine allocation procedures for allocating each NAPAP cell's emissions down to 10 km x 10 km, 5 km x 5 km, and 2 1/2 km x 2 1/2 km cells. This allocation was accomplished by either population or land use by cell.

Population for the Michigan side of the study area was taken from the Graphical Exposure Modeling System (GEMS), which was based on 1980 United States Census data. In contrast, the Ontario Ministry of the Environment provided population for the Ontario side for the year 1985. Because the two data sets were generated in two separate efforts, the procedures for developing population-based allocation factors had to be structured differently. For the Michigan side, population data was available by Block Group (BG); BG centroids were therefore located according to the study grid, and population was allocated to the specific study grid cell. Population allocation factors were then developed based on the ratio of population in individual grid cells within a specific NAPAP cell, to the total population in that NAPAP cell; speciated emissions for the NAPAP grid cell were then multiplied by that ratio for all source categories except mobile sources and area source categories which are more reasonably attributed to specific land uses rather than to population.

Allocation of population on the Canadian side was somewhat more complex. 1985 population data from Ontario MOE was gridded, but in a different network of grid cells than the network for this study. As a result, it was necessary to reallocate population in the Ontario grid to the study grid, and then develop a set of population allocation factors on the basis of the ratio of population in the study grid cells to the total population in the NAPAP cells.

Area source categories which were appropriately apportioned by population (e.g. those with per capita emission factors) were then calculated. Emissions for each pollutant in each study cell were calculated simply by multiplying the allocation factor for each study cell by the appropriate pollutant emission for the NAPAP cell in which the study cell is located.

Mobile Source Procedures – Mobile source emissions are a function of many specific factors, including vehicle fleet age distribution, vehicle fleet mix, vehicle fleet mileage accumulation, and temperature. Mobile source emissions are especially a function of total

traffic, as expressed by vehicle miles traveled (VMT). T[redacted] mobile source emissions, the usual [redacted]

Because mobile source emissions are so heavily influenced by VMT and other factors, it is best not to allocate areas with the greatest traffic by either population or land use. For this study, the Southeastern Michigan Council of Governments (SEMCOG), the organization responsible for transportation planning in most of Southeastern Michigan, provided VMT and other related data for most of the study grid network. Based on this data, and vehicle fleet characteristics provided by the Michigan DNR, MOBILE4 (EPA's mobile source emission factor model) was run to obtain VOC emission factors. Particulate emission factors were taken from EPA documentation (Carey, 1987) and other sources. Emissions were then calculated by grid cell by multiplying grid cell-specific VMT by grid cell-specific emission factors. Additional detail is provided in the emission inventory report.

Land Use Allocation Procedures - There were two non-mobile area source categories for which population was judged to be an inappropriate allocation parameter: ship/barge/boat traffic and pesticides. Ship, barge, and boat traffic was allocated either on the basis of shoreline for the Great Lakes Waterways (including the Detroit and St. Clair Rivers and Lake St. Clair), and on the basis of surface area for inland lakes. For inland lakes to be counted in this calculation, a minimum length of one half mile was adopted.

Recreational boating emissions were then allocated to inland lakes and to grid cells including the Great lakes waterways within a mile of the shoreline. Commercial ship and barge traffic was allocated only to the Great Lakes waterways, but including all grid cells with Great Lake waterways (not just those including shoreline areas). USGS quadrangle maps were used for identifying waterways, including the lengths of their shorelines and their surface areas.

Similarly, pesticide use is not well-correlated with population. Instead, pesticide use is based on agricultural land use. Based on pesticide data from several sources, a specific protocol was developed for estimating pesticide emissions. First, pesticide use by specific pesticide in Michigan counties (Wade, 1989), and Ontario as a whole (McGee, 1984) was

obtained. Second, Ontario pesticide use was allocated to counties by crop acreage. Third, county pesticide use was allocated to individual grid cells on the basis of agricultural land use, again using USGS maps. Finally, emissions were estimated using a specific emission estimation protocol based on the specific type of pesticide used, the amount of pesticide applied, and, in the case of pesticides no longer used, the residual amount expected in the soil.

Consideration and Inclusion of Additional Databases

The preceding sections have addressed how the initial emission inventory was developed. However, there is a broad range of information and data at Federal, state, provincial, and local governmental levels which is relevant to developing an air toxics inventory. PCFs as presented above are accepted as providing a representative estimate for the processes and/or industries which they were developed for. As with standard criteria pollutant emission factors though, individual factors may or may not be representative for a particular process or industry. It is very useful to use specific, available information on particular sources to augment any database developed purely from PCFs.

The Transboundary air toxics inventory effort was therefore developed to reflect other databases whenever possible. The databases accessed included state, provincial, and county databases and the SARA Section 313 Toxic Release Inventory System (TRIS) database. Each is discussed individually below.

State, Provincial, and Local Databases - The basic data set used for creation of the toxics database was the 1985 NEDS/NAPAP point and area source estimates for criteria pollutants. The 1985 database covers both U.S. and Canadian point and area sources and has the highest level of quality assurance of any similar deck. As this deck was created for criteria pollutants, it was necessary to supplement it in order to estimate emissions for the pollutants of concern in this study. Data was obtained from EPA (NESHAPs and TRIS), the Michigan Department of Natural Resources, the Ontario Ministry of the Environment, Wayne County Department of Health, and SEMCOG (Southeast Michigan Council of Governments) in order to make the inventory more comprehensive. This effort included:

- checking of stack data and other details left out of USEPA's NESHAPs database;
- quality assurance evaluations of individual points and/or facilities whose initial emission estimates appeared questionable; and
- obtaining data for smaller sources (such as chrome platers) which would not have been included in the NAPAP database, but would nevertheless have significance for inventories of specific, high toxicity pollutants.

This information was probably most critical for performing quality assurance checks on preliminary estimates. Preliminary estimates were submitted to the state and local agencies for review, and specific facilities were discussed in detail by telephone. While some facilities which were permanently closed after 1985 were eliminated from the database as a part of this process, facilities retaining permits but not in operation after 1985 were included. In this way, modeling for deposition from local sources should be relatively conservative. In addition, the Detroit municipal waste incinerator was added to the inventory.

SARA 313 (TRIS) Database - The submissions of July 1, 1988 (and after), were developed for the calendar year 1987. Emissions are reported on a plantwide basis, pollutant-by-pollutant. A review of the database reveals that frequently the most reported substances are organic solvents. Such a result is not surprising given that solvents are often raw materials that are purchased for use at specific facilities, and the quantities purchased are known. Solvent emissions of this sort are frequently (though not always) reported as fugitive emissions.

Many of the air toxics emissions at specific facilities though result from impurities in feed materials or as a result of chemical reactions related to the process. Some facilities, especially the smaller ones, are less likely to be aware of such specific emissions. However, because these processes are usually the source of criteria pollutant emissions, it is probable that these processes will be documented in both state and NAPAP databases. It is these databases that are the basis upon which PCFs are applied. Therefore, if the criteria pollutant inventories are relatively complete with respect to key processes at significant facilities, the TRIS database for process emissions should not be necessary.

As a part of this process, there was a need to evaluate specific TRIS listings to ensure that there was no overlap with other sources in the database. This effort was complicated by the similarity of names (especially given the multiple facilities of the major vehicle manufacturers in the area), and the fact that addresses or locations were sometimes ambiguous. After cross-checking of databases, telephone calls were made to specific sources where location information was either missing or questionable.

In summary, TRIS fugitive emissions estimates frequently were incorporated into the database, while TRIS process emissions usually were not (see discussion below on database finalization). Generally, information directly from facilities is preferable to indirect emission estimate techniques such as emission factors; in this case however, direct facility contacts were performed as a part of much of the NAPAP inventory. Quality assurance on TRIS process emissions in most cases is unknown at best. Fugitive emissions of solvents, which are frequently tied to solvent purchases, should be less subject to estimation errors, and in any event, are usually not covered in NAPAP.

Database Finalization - Based on the data sources and discussed above, the point source database combined information using the following priority:

1) NAPAP/PCF facilities;

2) NESHAPs facilities;

3) TRIS facilities (fugitive); and

4) TRIS facilities (process).

This prioritization scheme was used to exclude data of lower priority; only facilities which were not represented in a higher priority scheme were added at each level in order to minimize the potential for double counting. TRIS fugitive data was generally utilized whereas TRIS process estimates were only used when other facility data was not available. (The only exception was that TRIS process data was used when NESHAPs estimates were not based on site-specific data.) The database was then reviewed again to eliminate any duplicate records. In addition, several specific pollutants were reviewed when emissions seemed unreasonable, or if gaps were found in the database.

DISPERSION MODELING APPROACH

Choice of Model to be Used

Once the inventory was prepared, modeling of both area and point sources could proceed. Choosing a model for this analysis required consideration of a number of factors, including:

- the type of sources
- terrain
- extent of the study area
- the kinds of analysis (dispersion, deposition, etc.) needed

In addition, working with a single model was desirable in order to expedite the analysis.

The emissions database described above includes a wide variety of sources. Terrain is relatively flat, and the source-receptor distance is generally less than 50 kilometers. As indicated previously, both dispersion and deposition analysis were needed. For all of these reasons, the Industrial Source Complex-Long Term (ISCLT) Model was used for this analysis.

ISCLT is an EPA-recommended Gaussian dispersion model. It is appropriate for source-receptor distances up to 50 kilometers and can handle both point and area sources. It provides a significant advantage over other models (such as CDM) in that it provides estimates of settling and dry deposition, as well as dispersion. EPA's *Guideline on Air Quality Models* (USEPA/OAQPS, 1986a) recommends the use of ISCLT in combined rural and urban areas with "complicated sources," including such factors as "particle deposition, ...area sources," etc., "with averaging times of a month or more." Because this study is oriented towards long-term deposition model estimates, and carcinogenic risk from lifetime exposures, a long-term model is clearly appropriate.

Model Inputs and Procedures

Point Source Modeling – As explained above, the source decks were prepared on the basis of the ISCLT input requirements (USEPA/OAQPS, 1986b). For point sources, a total of 246 facilities were modeled. A significant problem with the point source deck was that many facilities lacked either stack parameters or locations. For missing stack data, one of three methods was utilized. If standard reference data for specific SCCs was available, it was used. Otherwise average parameters for the same SCC in the Transboundary deck, or average parameters for similar sources (such as all combustion sources) in the Transboundary deck were used. Stack parameters were then averaged for individual facilities. Missing locations were added first through cross referencing with the TRIS database to get latitude and longitude, which was then converted to UTM coordinates. Other locations were found by using industrial directories, or by direct phone calls, and some were determined by using city locations in conjunction with USGS maps.

Meteorological data was taken from Detroit Metropolitan Airport, which is a primary STAR station (Station No. 94847). The years 1982-1986 were utilized for this analysis. Over 50 percent of the time during these years, wind direction varied from south to west-northwest. Data had been preprocessed for use in ISC.

Table 3-1 provides a summary of the inputs used in this analysis. The choices of inputs is typical for an urban area in a regionwide analysis. Microscale effects, such as stack-tip downwash, were not evaluated. Urban option "4" was chosen, which makes no adjustment to stability category information in the meteorological data set used, and utilizes the urban Briggs dispersion curves (USEPA/OAQPS, 1986b). For the estimation of ambient concentrations through these runs, the deposition rate was assumed to be zero.

Receptors were set up at the centroids of each of the 384 grid cells. Elevations of these receptors were determined by using USGS quadrangle maps. Because there was a concentration of point sources in the Port Huron/Sarnia area, six grid cells (327, 328, 329, 343, 344, and 345; see Figure 2-2) were quartered to give a total of 18 extra receptors for the point source runs.

TABLE 3-1

ISCLT MODEL OPTIONS AND VALUES FOR MODELING ANALYSIS

Calculate (Concentration = 1, Deposition = 2)	ISW (1) = 1
Receptor Grid System (Rectangular = 1, Polar = 2)	ISW (2) = 1
Discrete Receptor System (Rectangular = 1, Polar = 2)	ISW (3) = 1
Terrain Elevations Are Read (Yes = 1, No = 0)	ISW (4) = 1
Input/Output Tape Option (Yes = >3, No = 0)	ISW (5) = 0
List All Input Data (No = 0, Yes 3)	ISW (6) = 3
List concentrations (or total deposition) for the following:	
Seasonal(1), Annual(2), Both(3)	ISW (7) = 2
Sources (individual = 1, combined = 2, both = 3)	ISW (8) = 3
Rural-Urban Option (Urban = 1, 2, 4, Rural = 3)	ISW (9) = 4
Calculate Maximum 10 Concentrations (No = 0, Yes = 2)	ISW (10) = 2
Print Maximum 10 Concentrations (No = 0, Source Contribution = 2)	ISW (11) = 2
User-Specified 10 Receptors (Yes = 1, No = 0)	ISW (12) = 0
Output to Printer (Yes = 0, No = > 0)	ISW (13) = 0
Tape Input (Unit 2 = 0, No = > 0)	ISW (14) = 0
Output to Unit 3 (Yes = 0, No = > 0)	ISW (15) = 0
Print the following types of tables:	
Each table on new page (Yes = 0, No = 1)	ISW (16) = 0
57 lines per page (Yes = 0, No = > 0)	ISW (17) = 80
Met. data format (6F 10.0 = 0, No = 1)	ISW (18) = 1
Program Calculates Final Plume Rise Only (Yes = 0, No = 1)	ISW (19) = 1
Stack-tip Downwash (Yes = 0, No = 1)	ISW (20) = 1
Buoyancy induced dispersion (Yes = 0, No = 1)	ISW (21) = 0
Regulatory default mode (Yes = 0, No = 1)	ISW (22) = 0
Pollutant being modeled (SO2 = 0, Others = 1)	ISW (23) = 1
Input debug option (Yes = 0, No = 1)	ISW (24) = 0 or 1
Program reads receptor heights above ground (No=0, yes=1)	ISW (25) = 0

Once the modeling inputs were finalized, ISCLT was run at a "unit" emission rate. Such a "normalized" modeling approach was utilized in order to reduce the number of modeling runs. Once the modeling for a unit emission rate was accomplished for 246 sources, programs were written to produce cross calculation of source strengths and unit modeling results. Individual source contributions were then added pollutant-by-pollutant, receptor-by-receptor, in order to produce ambient concentrations of each pollutant at each receptor contributed by point sources.

Area Source Modeling - The ISCLT area source inputs are similar to those used in the point source modeling. Meteorological data and model options were the same. Source strength for individual pollutants were determined simply by dividing emission rates by the grid cell size. Receptors were again set up at the center of the grid cells, though no extra receptors were modeled in the Port Huron/Sarnia area. Area source contributions to ambient concentrations were again determined by multiplying unit modeling results (this time for area sources) by source strengths by pollutant, and adding contributions pollutant-by-pollutant, receptor-by-receptor.

Determination of Total Ambient Concentrations by Pollutant - A risk assessment needs population, a measure of the degree of risk a particular pollutant poses (a unit risk factor), and a concentration of that pollutant. Ambient concentrations are based on the combination of the point source contribution, the area source contribution, and the background concentration which is determined and assumed. The procedures for determining the point and area source contributions are provided above. Background concentrations and inflow from areas outside the study area were assumed to be zero, with two exceptions, both of which were documented in the Southeast Chicago air toxics report (Summerhays, 1989). Formaldehyde, which is generated by photochemical reactions, was assumed to have a background concentration of 2.23 $\mu g/m^3$. Carbon tetrachloride, which is very stable in the atmosphere, was assumed to have a background concentration of 0.76 $\mu g/m^3$.

RISK ASSESSMENT METHODOLOGY

The discussion above presents the methodologies used for estimating air toxics emissions and performing dispersion modeling. The discussion below presents both an

overview of risk assessment techniques and also the methodologies for risk assessment used in this study.

An Overview of Risk Assessment Techniques

The National Academy of Sciences defines four steps of risk assessments: hazard identification, exposure assessment, evaluation of dose-response relationships for the pollutants in the study, and estimation and characterization of risk. Hazard identification involves identifying an exposure scenario, e.g., inhalation of air contaminants, which may be causing adverse health effects. Exposure assessment involves evaluating the ambient concentrations of the pollutants to which the public is exposed. The principal method in this study for assessing exposure is to estimate emissions and then estimate atmospheric dispersion of these emissions, resulting in ambient concentration predictions which can be paired with population data for specific receptor sites. The evaluation of dose-response relationships involves the estimation of cancer risk factors, representing the cancer risk estimated to result from breathing a unit concentration (e.g., one millionth of a gram per cubic meter of air). Finally, estimation and characterization of risk involves compiling and analyzing all this information in a way that provides useful statements about risk.

It is instructive to compare the methods of risk assessment to the methods of epidemiological studies of cancer statistics. Epidemiological studies provide a more direct means of considering the impact of environmental contaminants on cancer rates. Unfortunately, due to the difficulties of distinguishing environmental factors from other factors, such studies are often inconclusive. Further, such studies generally do not even attempt to consider the separate influences of the various sources of the various environmental contaminants. While epidemiological studies may of course be used as a useful part of some risk assessments, a regional air inhalation risk assessment thus has different purposes than the purposes of most epidemiological studies. Epidemiological studies, if conclusive, can provide a better evaluation of the correlation between air pollution and cancer statistics. However, risk assessments, especially regional risk assessments, provide a more detailed data base on the potential relative significance of different source types and different pollutants. Further, due to the long periods of exposure that are considered to be involved in cancer induction, current cancer statistics probably reflect exposures over the last several decades. In contrast, studies using standard

USEPA methods of risk assessment can associate risk with current air pollutant concentrations. Furthermore, given the mobility of population in the United States, cancer statistics reflect exposure in multiple areas where members of the studied population have lived. In contrast, risk assessments focus specifically on estimated impacts of exposure to pollutant concentrations.

As discussed previously in this chapter, risk assessments need estimates of concentrations of pollutants, the population exposed, and unit risk factors to determine carcinogenic risk to a population. The dispersion modeling section discussed above presents the methodologies for estimating ambient concentrations of different pollutants. The population used in this risk assessment is the same as that described and apportioned in the land use allocation procedures subsection in the "Emissions Estimate" section above. It was assumed that the population of the grid cell was exposed to the ambient concentration predicted at the receptor located at the centroid of the grid cell. The remaining element, carcinogenic risk factors, are discussed below; both background of how unit risk factors are developed and used in typical EPA risk assessments, and the specific unit risk factors used in this study are presented.

Cancer Risk Factors

Background – The relationship between concentration and the increased probability or risk of contracting cancer that exposure to each pollutant may cause. This relationship is commonly expressed in terms of a unit factor, representing the risk estimated to result from exposure to a unit concentration of a pollutant. For example, if a pollutant has a unit risk factor of $1x10^{-4}$ per $\mu g/m^3$, then lifetime exposure to 1 $\mu g/m^3$ (1 millionth of a gram of the pollutant per cubic meter of air) would be estimated to increase the probability of contracting cancer by $1x10^{-4}$ or 1 chance in 10,000. The probability or risk of contracting cancer is generally treated as linear within the range of actual exposure conditions, so that in the example above, exposure to a concentration of 3 $\mu g/m^3$ would be estimated to increase cancer risks to $3x10^{-4}$ or 3 chances in 10,000.

There is a lack of data where large numbers of people are exposed to typical environmental concentrations, where the concentrations and the resulting number of cancer cases are well defined for several subpopulations, and where confounding influences from other causes of cancer can be clearly factored out. Therefore, a variety of methods,

scientific judgements and assumptions are used to assess the relationship between exposure to a pollutant and the resulting risk of contracting cancer. For some pollutants, sufficient data do exist for specifiable human exposure circumstances to estimate the exposure levels and to evaluate the cancer risks that apparently result. The interpretation of these statistical data is generally designed to derive a maximum likelihood estimate of the unit risk factor (i.e., deriving a unit risk factor which the data suggest will have the greatest likelihood of accurately representing the ratio between exposure and cancer risk for the conditions of the study). In general, the exposures that can be studied are higher than typical ambient concentrations, and so extrapolation of the exposure-cancer risk relationship must be performed. This extrapolation of the dose-response relationship down to lower exposure levels uses conservative methods, so as to decrease the likelihood of underestimating risks.

For a majority of pollutants, however, no human exposure situation can be sufficiently characterized to support the derivation of a unit risk factor. Thus, while human data is preferable, it is usually not available, and the only data for deriving unit risk factors for these pollutants will generally be from studies involving animals. These studies provide statistical data which by various interpretations can yield alternative unit risk factor estimates. The usual interpretation method is to select a 95% upper confidence level value. This signifies that the selected unit risk factor is the value which has a 95% likelihood of not understating the true risk factor indicated by the data. It should be noted that this discussion refers only to the conservatism inherent in the statistical interpretation of cancer data, which is not the only element of conservatism in the unit risk factor. As with the maximum likelihood estimate, a downward extrapolation from studied exposures to ambient exposures is necessary, and this extrapolation is done in a way that adds conservatism. (For animal studies, practical considerations generally require studied exposures to be higher than ambient exposures. For example, a study involving 100 animals cannot provide a meaningful result if the risk is 1 in 1,000,000.) The extrapolation of the unit risk factor applicable to typical ambient concentrations involves best scientific judgement of a plausible yet conservative extrapolation. With animal studies, an additional adjustment is made from animal carcinogenicity to human carcinogenicity based on differences in body weight and breathing rate, again involving best scientific judgement of a plausible yet conservative extrapolation. Thus, the methods of extrapolating unit risk

factors add some conservatism to the conservatism inherent in the use of a 95% upper confidence limit.

The relationship between pollutant concentration and cancer risk is a function of both the quantity of pollutant inhaled and the body's reaction to the inhaled quantity. Unit risk factors are designed to estimate the cancer risk resulting from inhaling a unit concentration for 24 hours a day for a 70 year lifetime. Similarly, cancer risks in this study are estimated by assuming that Transboundary area residents are exposed to the estimated concentrations for 24 hours per day for a 70 year lifetime. Clearly, these residents spend some time outside the study area and spend some time indoors, but the absence of knowledge of pollutant concentrations in these other environments makes it impossible to make upward or downward adjustments according to these other exposures.

In addition to variability in carcinogenic strength, there is also variability in how much evidence exists to indicate more fundamentally whether individual pollutants are in fact carcinogenic. Therefore, USEPA has established a classification system describing the weight of experimental evidence that a pollutant is carcinogenic. The classifications used by USEPA are: A - human carcinogen; B - probable human carcinogen; C - possible human carcinogen; D - not classifiable as to human carcinogenicity; and E - evidence of noncarcinogenicity in humans. These ratings reflect the following types of evidence: A - "sufficient" human data show carcinogenicity; B - is subdivided into B1 and B2, in which either "limited" human data or "sufficient" animal data show carcinogenicity; C - human data are inadequate or nonexistent but limited animal data show carcinogenicity; D - data to assess carcinogenicity are inadequate or nonexistent; and E - well designed studies suggest that the pollutant is noncarcinogenic. More detailed definitions of these classifications can be found in USEPA's Risk Assessment Guidelines of 1986. For clarity, references to group A pollutants in this report will use the term "known human carcinogen."

The classifications in the weight of evidence approach are intended to indicate the strength of the evidence of carcinogenicity independently of any evaluation of carcinogenic strength. For some pollutants, a greater weight of evidence of carcinogenicity also signifies a better data base from which to estimate unit risk factors, but this is not the case for all

pollutants. As yet, no equivalent system has been developed to address the accuracy of the unit risk factors.

Unit Risk Factors Used in This Study - This study found and quantified emissions for numerous presumed carcinogens (see Chapter 4). Table 3-2 provides the names of these pollutants, the weight of evidence classification, the unit risk factor used in this study, and whether this risk factor is calculated as a 95% upper confidence level (UCL), a maximum likelihood estimate value (MLE), or a best estimate (BE). This table also shows which USEPA office developed the unit risk factor. In this table, IRIS (Integrated Risk Information System) signifies risk factors that have received agency-wide review. Other values have not received agency-wide review but have been developed by the Office of Health and Environmental Assessment in the Office of Research and Development (designated OHEA), by the Office of Air Quality Planning and Standards (designated OAQPS), or by the Office of Solid Waste (designated OSW).

Several of the pollutants in Table 3-2 represent mixtures of compounds. One such mixture is designated in Table 3-2 as "Benzo(a)pyrene (POM)." Benzo(a) pyrene(B(a)P) is the most studied member of the class of compounds known as polycyclic organic matter (POM). This study inventoried emissions and estimated concentrations of the full class of POM compounds as well as B(a)P individually. A common approach is to estimate risk by multiplying the POM concentrations times the benzo(a)pyrene unit risk factor. While some POM compounds are probably more carcinogenic and other POM compounds are less carcinogenic, this approach in effect assumes that the average cancer potency of the full range of POM compounds equals the cancer potency of benzo(a)pyrene. This approach has been used in this study.

Another mixture shown in Table 3-2 is coke oven emissions. For this mixture, a unit risk factor for the full mixture has been developed (based on epidemiological analysis of occupational exposure data). This mixture includes substantial quantities of other pollutants in this study, including polycyclic organic matter and benzene. However, no effort was made to assess emissions or risk from these coke oven gas constituents individually. Instead, the emissions estimates, the unit risk factor, and the risk estimates for coke oven emissions are designed to address the emissions, toxicity, and risk of the full mixture emitted from coke batteries.

TABLE 3-2

SUMMARY OF UNIT RISK FACTORS

Pollutant	Weight of Evidence Rating	Inhalation	Type of Risk Factor	Source of Data	Pollutant ID
Acrylonitrile	B1	0.000068	UCL	IRIS	43704
Arsenic	A	0.0043	MLE	IRIS	32103
Asbestos	A	0.0076	BE	IRIS	32801
Beryllium	B2	0.0024	UCL	IRIS	32105
Benzene	A	0.0000083	MLE	IRIS	45201
Benzo(a)pyrene(POM)	B2	0.0017	UCL	OAQPS	46719
1.3 Butadiene	B2	0.00028	UCL	IRIS	43218
Carbon Tetrachloride	B2	0.000015	UCL	IRIS	43804
Cadmium	B1	0.0018	MLE	IRIS	32110
Chlordane	-	0.00037	-	IRIS	51104
Chloroform	B2	0.000023	UCL	IRIS	43803
Chromium	A	0.012	MLE	IRIS	32112
Coke Oven Emissions	A	0.00062	UCL	IRIS	4COKE**
Dioxins	B2	33.	UCL	OHEA	4DIOX**
Epichlorohydrin	B2	0.0000012	UCL	IRIS	43863
Ethylene Dibromide	B2	0.00022	UCL	IRIS	43837
Ethylene Oxide	B1	0.0001	UCL	OHEA	43601
Formaldehyde	B1	0.000013	UCL	IRIS	43502
Gasoline Vapors	B2	0.00000066	UCL	OAQPS	98GAS**
Heptachlor	-	0.0015	-	IRIS	51109
Methyl Chloride	C	0.0000018	UCL	OHEA	43801
Methyl Chloride	B2	0.00000047	UCL	OHEA	43802
PCBS	B2	0.0012	UCL	OSW	4PCBS**
Perchlorethylene	B2	0.00000095	UCL	OHEA	43817
POM	-	0.0017	*	OAQPS	98POM**

*Assumed to be identical to B(a)P.
**Special code adopted for this study.

TABLE 3-2 (CONT'D)

SUMMARY OF UNIT RISK FACTORS

Pollutant	Weight of Evidence Rating	Inhalation	Type of Risk Factor	Source of Data	Pollutant ID
Styrene	B2	0.00000057	UCL	OHEA	45220
Trichloroethylene	B2	0.0000017	UCL	OHEA	43824
Vinyl Chloride	A	0.000084	UCL	OHEA	43860

KEY

WEIGHT OF EVIDENCE:

A- Known human carcinogen
B- Probable human carcinogen
B1- Based on "limited" human data
B2- Based on "sufficient" animal studies
C- Possible human carcinogen

TYPE OF RISK FACTOR:

UCL-95% upper confidence limit
MLE-maximum likelihood estimate
BE-best estimate

SOURCE OF DATA:

IRIS-Integrated Risk Information System
OAQPS-Office of Air Quality Planning and Standards
OHEA-Office of Health and Environmental Assessment
OSW-Office of Solid Waste
Region V-Region V Air and Radiation Division

NOTE - Though IRIS provides a unit risk factor for nickel, this factor is for a form of nickel not emitted in the United States (Blakley, 1990).

A third mixture shown in Table 3-2 is dioxin. In this study "dioxin" represents a class of 75 chlorinated dibenzo-dioxins and 135 chlorinated dibenzo-furans. The unit risk factor shown in Table 3-2 is for 2,3,7,8 - tetrachloro-dibenzo-dioxin (2,3,7,8 - TCDD), the best studied dioxin. Other dioxins were inventoried on the basis of toxic equivalents, i.e., what mass of 2,3,7,8 - TCDD would have equivalent toxicity to the given mass of identified dioxin. For example, 10 grams of 2,3,7,8 - tetrachloro-dibenzo-furan, having an estimated toxicity equivalence factor of 0.1, would be inventoried as if it were 1 gram of 2,3,7,8 - TCDD.

Two other mixtures shown in Table 3-2 are gasoline vapors and polychlorinated biphenyls (PCBs). The unit risk factor for gasoline vapors was derived from a study of the full mixture, though it does not include the impact of gasoline's benzene component. The unit risk factor for PCBs was derived for a representative compound of this set of compounds. Finally, it should be noted that "hexachlorobenzene" emissions in some cases included emissions of other chlorinated benzene compounds, a mixture which was conservatively treated as having the carcinogenicity of hexachlorobenzene.

Chromium also warrants special comment. For chromium, the unit risk factor is only for the hexavalent (+6) form of chromium. Emissions were originally calculated for total chromium. Hexavalent proportion factors were then multiplied by the resulting total chromium emission estimate to match with the unit risk factor.

The above discussion addresses the calculation of risks from individual pollutants. This study also seeks to estimate the combined impact of all the pollutants included in this study. The methodology recommended in the "Chemical Mixtures Risk Assessment Guidelines" (part of USEPA's Risk Assessment Guidelines of 1986) is to estimate total risks as a linear sum of the individual pollutant risks, in the absence of information suggesting otherwise. It is possible that exposure to some combinations of pollutants may cause a greater risk (synergism) or a lesser risk (antagonism) than the sum of the risks resulting from exposure to the substances individually. However, there are no clear means of quantifying any synergistic or antagonistic effects from exposure to the complex and variable mixtures in the Transboundary area atmosphere, if in fact such effects are occurring. Therefore, the method for combining risks used in this study was to sum the risks estimated for individual pollutants.

The unit risk factors used in this study reflect the best judgements of USEPA scientists in evaluating available evidence both as to the interpretation of specific studies and as to the procedures that most reliably extrapolate unit risk factors from these studies. Nevertheless, the uncertainties in the unit risk factors are probably the greatest uncertainties in this study. These uncertainties arise from the significant extrapolations such as from high concentrations to lower concentrations and from rats or mice to humans that are necessary to estimate the risk factors.

The Risk Assessment Guidelines of 1986 discuss the significant assumptions and therefore the significant uncertainties that are necessary in developing unit risk factors. In summary, these assumptions and uncertainties are as follows: (1) Exposure to any amount of the substance, no matter how small, is assumed to represent an increased probability of cancer. There is uncertainty that cancer impacts may occur only above some pollutant-specific threshold concentration; (2) For risk factors based on animal studies, the development of cancer in humans is analogous to the development of cancer in the animals. There is uncertainty that the biological process of cancer formation is the same process in humans as in animals. For this and other reasons, there is also uncertainty in the quantitative extrapolation of the relationship between cancer risks and exposure for humans from the relationship for animals; (3) Information on the carcinogenicity of substances at "high" concentrations can be used to predict the effects at "low" concentrations; and (4) The increased probability of cancer incidence is proportional to the concentration of the substance at low concentrations.

CHAPTER 4

RISK ASSESSMENT

Chapter 3 described the methodologies utilized in this study. This chapter presents the study results, as well as a discussion of how the results should be interpreted.

EMISSIONS

Summary

Table 4-1 provides a summary of the emission inventory results of this study. [redacted] releases were identified for a total of 42 of the 57 pollutants studied. No emission releases were identified for the other 15 pollutants (acrylamide, di-n-octyl phthalate, ethyl acrylate, hexachlorobenzene, hexachlorobutadiene, hexachloroethane, melamine, octochlorostyrene, vinylidene chloride, aldrin, heptachlor epoxide, methyl chloride, dibenz(a,h) anthracene, methyl-benzanthracenes, and hydrogen sulfide). It should be stressed that chromium emissions reported here include only hexavalent chromium.

Emission totals for each of the 42 pollutants in Table 4-1 are allocated to six major source groupings, as follows:

Motor Vehicle Manufacturing – All facilities directly involved with motor vehicle assembly operations, especially manufacturing of vehicle bodies and parts, plus vehicle assembly (except fuel/waste combustion sources);

Steel Mill and Coke Operations – All facilities directly involved with steel and coke manufacturing, especially steel mills, including blast furnaces and coke ovens (except fuel/waste combustion sources);

Mobile Sources-Highway motor vehicles (including cars, busses, and trucks) including refueling operations at gasoline stations;

TABLE 4-1

SUMMARY OF EMISSIONS FROM POINT, AREA AND MOBILE SOURCES (tons/year)

Pollutant Name	Motor Vehicle Manufact.	Steel Mill and Coke Operations (non-Motor Vehicle)	Mobile Sources	Utilities and Other Fuel Combustion	Other Industrial Sources	Other Area Sources	Total Emissic from e Sources
1-3 Butadiene	21.7600	23.9880	1782.3188	10.6830	1373.7975	0.0000	3212.5
Acrylonitrile	0.0000	0.0000	0.0000	2.0000	0.0000	0.0000	2.0
Allyl Chloride	0.0000	0.0000	0.0000	0.0000	0.9750	0.0000	0.9
Arsenic	2.7220	1.1960	0.0000	6.4691	2.8759	0.0000	13.2
Asbestos	0.0000	0.0000	11.3005	0.0000	0.0010	0.0000	11.3
Benzene	35.5340	2075.7050	3708.2831	822.0570	803.2779	451.0937	7895.9
Benzo(a)pyrene (POM)	0.0000	0.0000	4.5194	2.8890	0.0000	0.0000	7.4
Beryllium	0.5820	0.7510	0.0000	11.3260	0.2340	0.0000	12.8
Cadmium	0.6630	1.1000	0.0000	3.6830	1.1513	0.0000	6.5
Carbon Tetrachloride	1.2750	0.0000	0.0000	3.1680	15.5972	0.0000	20.0
Chlordane	0.0000	0.0000	0.0000	0.0000	0.0000	0.6630	0.6
Chloroform	1.6530	0.0000	0.0000	4.1140	2.3399	0.0000	8.1
Chromium	0.8260	0.0430	0.0000	0.7566	2.6007	0.0000	4.2
Chrysene	0.0000	0.0000	0.1559	6.4378	0.0000	0.0000	6.5
Coke Oven Emissions	0.0000	752.6970	0.0000	0.0000	0.0000	0.0000	752.6
Diazinon	0.0000	0.0000	0.0000	0.0000	0.0000	1.9738	1.9
Dibutyl Phthalate	0.0000	0.0000	0.0000	0.0000	0.7796	91.6807	92.4
Dioxins	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0
Epichlorohydrin	2.5250	0.0000	0.0000	0.0000	0.0000	0.0000	2.5
Ethylene Dibromide	0.0000	0.0000	0.0000	0.0000	0.0000	47.3129	47.3
Ethylene Dichloride	0.0000	0.0000	0.0000	0.0000	131.0205	0.0000	131.0
Ethylene Oxide	0.0000	0.0000	0.0000	0.0000	3.9000	0.0000	3.9
Fluoranthene	0.0000	0.0000	1.2737	9.3846	0.0000	0.0000	10.6
Formaldehyde	10.3420	23.3530	1155.0482	602.5404	145.5272	187.3932	2124.2
Furans	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0
Gasoline Vapors	0.0000	0.0000	69165.6903	0.0000	0.0000	0.0000	69165.6
Guthion	0.0000	0.0000	0.0000	0.0000	0.0000	3.6393	3.6
Heptachlor	0.0000	0.0000	0.0000	0.0000	0.0000	0.1027	0.
Lead	5.6730	20.2290	88.5033	149.7380	4.3371	0.0000	268.4
Mercury	0.1250	0.0990	0.0000	3.6561	0.0084	0.0000	3.8
Methyl-Chrysene	0.0000	0.0000	0.0000	3.6152	0.0000	0.0000	3.6
Methylene Chloride	54.9190	0.9000	0.0000	9.8260	17.4806	208.5408	291.6
Nickel	6.5860	6.6510	0.0073	48.4127	2.5195	0.0000	64.
PCBS	0.0420	0.0000	0.0000	0.1010	0.1250	0.0000	0.
POM	0.2740	0.0910	50.1102	78.0112	0.0000	0.0000	128.
Parathion	0.0000	0.0000	0.0000	0.0000	0.0000	0.4753	0.
Perchlorethylene	48.9550	0.0000	0.0000	5.4190	0.5130	3028.6457	3083.
Phenanthrene	0.0000	0.0000	0.0000	20.4742	0.0000	0.0000	20.
Selenium	0.3170	0.4090	0.0000	3.7983	0.5486	0.0000	5.
Styrene	0.7500	0.0000	3.4432	3.2950	1210.6033	18.9664	1236.
Trichloroethylene	312.1550	2.1500	0.0000	7.1920	63.9340	1072.7115	1458.
Vinyl Chloride	0.0000	0.0000	0.0000	0.0000	83.4477	0.0000	83.

Utilities and Other Fuel Combustion-Coal, oil, and gas combustion sources, including utilities, industrial facilities, commercial and institutional facilities, and residential buildings, plus all waste incineration sources (including municipal waste. sewage sludge, etc.);

Other Industrial Sources-All other point sources, including refineries, chemical manufacturing, and documented solvent use at industrial facilities including degreasing; and

Other Area Sources – All other residential, agricultural, and small industrial sources, including architectural coatings, consumer solvents, pesticide use and residual pesticide loss from agricultural land, and solvent use from small businesses.

Based on the results shown in Table 4-1, several conclusions can be reached. First, many of the pollutants are emitted primarily by one type of source. For example, many of the metals come primarily from fuel combustion sources due mainly to trace contaminants in the fuel. Second, mobile sources contribute a substantial portion of the mass of toxic emissions, including significant portions of benzene, butadiene, benzo(a)pyrene, formaldehyde, lead, and polycyclic organic matter (POM). Gasoline vapor emissions are attributed completely to mobile sources (as a result of vehicle refueling). Third, the main pollutants for motor vehicle manufacturing (the leading industry in the region) appear to be primarily degreasing solvents, and a few other organics. Fourth, "[illegible]," including dry cleaners, small businesses, and residences contribute substantially to the overall emission of chlorinated solvents, including methylene chloride, perchloroethylene, and trichloroethylene. Finally, the primary pollutants from steel and coke operations were coke oven emissions and benzene.

When reviewing the table, it is important to understand the interrelationships between some of the pollutants. First, B(a)P and the other polynuclear aromatic hydrocarbons (chrysene, fluoranthene, methyl chrysene, and phenanthrene) were calculated as a portion of total POM emissions; as a result these categories are not mutually exclusive. Second, benzene is a part of gasoline vapors, but because unit risk factors were available for both benzene and gasoline vapors as individual substances, the

benzene component was considered separately, and reported as a part of total benzene emissions. Finally, coke oven emissions were reported separately; the POM component was not reported, even though POM is a primary constituent.

Discussion

Data Inputs-In any study of this type it is desirable to obtain and use data for the same year or time frame so the analysis is internally consistent. For this study, the goal was to perform the analysis consistent with conditions for the mid-1980s, with [redacted]. In any event, [redacted]. Most of the point source data, because it came from the 1985 NAPAP effort, is valid for 1985. The main exception was the TRIS data, which (because it resulted from the first year of reporting under Section 313 of the Superfund Amendments and Reauthorization Act (SARA) of 1986) was based on calendar year 1987. In addition, the Detroit incinerator was built after 1985, but was included because of the possibility that its emissions could be significant. Emission estimates for this source were based on a stack test. Additional control requirements have been developed for the incinerator which will be implemented in the future.

Data for mobile sources is mixed. Emission factors were generated for the year 1987, but traffic estimates were for the year 1988. As a result, emission factors may be somewhat low because [redacted] on the other hand, [redacted] (total VMT by grid cell) [redacted]. As a result, the net effect of these two factors versus a 1985 estimate is probably not significant.

For area sources emission calculations, two of the benefits of using the 1985 NAPAP/NEDS emission totals as a starting point were that data on both sides of the United States/Canadian border were generated consistently, and that the data generated was for the same base year (1985). However, as mentioned in Chapter 3, population data for Michigan was based on 1980, while population for Ontario was based on 1985.

Calculational Approaches-The approach for generating emission estimates for large numbers of potential sources proved very effective. Given the background

documentation for the PCFs (USEPA/OAQPS, 1988a and b), it also provides the opportunity for analysts and users of the data to evaluate the basis of estimates for particular sources.

A quick review of this list shows that the TRIS database was a useful adjunct to the other databases reviewed. There were a number of facilities which were not covered through the other database checks, but nevertheless did report fugitive emissions under SARA 313. Similarly, USEPA's NESHAPs database identified several facilities which were otherwise not included in other databases. This success seems to confirm the basic strategy of using multiple databases to maximize the probability of establishing a comprehensive inventory.

Interpretation of Results - As mentioned above, out of the 57 study pollutants, the database has emission estimates for 42. In some instances (e.g. benzene, perchloroethylene, and trichloroethylene), there are numerous entries in the point source database; in others, there are only a few entries at most. This is not a surprising result. The data available to support the PCFs used in this study is extensive but some of the substances on the list of 57 pollutants are specialized chemicals which are generated or used in limited situations. Some of the pollutant totals of zero simply reflect emissions of near zero. The lowest emission total that may be reflected in the database is 0.0005 tons per year (rounded to 0.001 tons per year) or one pound per year. It should be noted that even if emissions of pollutants within the study area are at or near zero, atmospheric deposition source contributions from outside the study area may be significant.

It is worth noting that a number of the pollutants on the original list were not included in the final point source emission estimates, particularly a number on the list of "organic/chemical production and reactions" pollutants. There may indeed be emissions (probably minimal) of such compounds. In a diverse industrialized area such as the 10-county study area, it would not be surprising that a given industrial facility would be using a particular compound, producing it as a final product, or creating it as an incidental by-product of another process[1]. However, the use of a combination of databases, as well as

[1]For example, in the State of New Jersey, which maintains a raw material database in addition to a process (SCC) database, usage of certain organics was documented even though the process database was somewhat incomplete (Carhart, Cornman, Koucky, and Opperman, 1988).

the involvement of Federal, state, provincial, and local state agency representatives as a part of the quality assurance activities undertaken in this project, should minimize the possibility that any important point source has been omitted.

A significant portion of the pollutant list was focused on substances included in the International Joint Commission's (IJC's) "critical pollutant list." The IJC has identified 11 pollutants as having adverse impacts on the Great Lakes as a result of potential point source emissions. These pollutants are as follows:

Mercury
Alkylated Lead
Total Polychlorinated Biphenyls
Hexachlorobenzene
Benzo-a-pyrene
2,3,7,8-tetrachlorodibenzo-p-dioxin
2,3,7,8-tetrachlorodibenzofuran
Mirex*
Toxaphene*
DDT*
Dieldrin*

Seven of the above compounds were inventoried for the study while the remaining four compounds (*) were not included due to either discontinued production or limited usage within the United States.

It should be noted that alkylated lead emissions were included in the inventory as lead in proportion to the lead content of the emissions. However, alkylated lead emissions as such can be expected to be concentrated in the mobile source category. On the basis of relative atomic and molecular weights, alkylated lead emissions amount to approximately 56 percent greater than mobile source lead emissions, or a total of roughly 138 tons/year.

Mercury in this inventory is primarily a result of fuel combustion, including waste incineration. Incinerators, including the Detroit waste incinerator, contribute slightly more than a ton of total of four tons, while point source coal and oil-fired boilers (including utilities) contribute about two tons.

Benzo(a) pyrene (B(a)P) is also primarily the result of fuel combustion, with a majority coming from mobile sources. Emissions of B(a)P, like the emissions of other individual polynuclear aromatic hydrocarbons (PAH) included in this inventory (chrysene, fluoranthene, methyl chrysene, and phenanthrene) were determined by proportions of POM emissions. For the other PAH, emissions were primarily or exclusively associated with stationary source fuel combustion. However, this result may be only a consequence of the lack of available data on mobile source emissions of these specific PAHs.

The specific dioxin and furan compounds in the IJC list were included in emission estimates of total dioxins and furans. No sources of these sources were found (i.e., above 0.0005 tons/year), with the exception the Detroit waste incinerator. Emission estimates for this source were six pounds of dioxins per year and six pounds of furans per year (based on a stack test), but as indicated above, proposed changes at the facility may reduce the emissions of both pollutants.

Roughly a quarter of a ton per year (slightly over 500 pounds) of PCBs were found in this study. About half of this total was due to one source in the TRIS database, and the others were due to documented waste oil use; this data was provided by the Wayne County Air Pollution Control Division. As with dioxins and furans, these estimates were made after a thorough review of both national and local databases.

No emissions of hexachlorobenzene (the remaining IJC critical pollutant included) were determined as a result of the calculations in this study. Hexachlorobenzene is emitted as a by-product in the production of a variety of chlorinated organic compounds and as a contaminant in pesticides (Howard, 1989). However, no specific industrial sources of this pollutant were confirmed, and there was no reliable, available information on hexachlorobenzene pesticide contamination.

Most of the other pollutants for which no emissions were determined are specialty chemicals, by-products of chemical processes, pesticides and pesticide derivatives, and specific polynuclear aromatic hydrocarbons. As with hexachlorobutadiene, it appears that there are no facilities in the area with the sorts of processes to produce emissions of these pollutants. However, in some cases, the PCF and other databases and references may not

have provided enough detail to allow a calculation. In any event, it should be stressed that emission totals of individual pollutants were reported as zero when emissions of individual sources were less than one pound per year.

RISK ASSESSMENT RESULTS

Summary

Table 4-2 provides a summary of the incidences of additional cancer cases predicted by this study allocated to the responsible pollutant. Again, t[redacted] based on the concentrations at the centroids of the grid cells and the population allocated to those cells.

Discussion

Data Input – Chapter 3 included a discussion of the methodologies used in developing data for exposed populations and unit risk factors two primary parameters for any risk assessment. The population data used should be a fair representation of the population exposed, subject to the limitations of the standard risk assessment assumptions used, particularly the assumption that there is no population movement during 70 years. It is worth noting that preliminary reported results of the 1990 United States census indicate decreased population in the City of Detroit, which is a large part of the core area. If this trend is confirmed, and if a similar investigation to this study for 1990 were performed, it is likely that the results would show that the relative distribution of risks would be changed, and the total incidences in the core area would be lower.

Calculational Techniques – As a result of the approach used in this study, an area of highest incidence receptor has been predicted for both the Michigan side and the Ontario side (see below in the subsection on "Interpretation of Results"). The fact that these two areas were predicted as the locations of the greatest cancer incidence does not mean that these precise points are the absolute locations of the highest risks. There are a number of reasons for this caveat, including the model inputs and the choice of model. In addition to the uncertainties in the emission data, the simplifications in the point source stack data introduce a source of uncertainty. With respect to the choice of model, the use of ISCLT for area sources may provide lower concentration estimates than other models; a recent

TABLE 4-2

SUMMARY OF ESTIMATED EXCESS CANCER CASES BY POLLUTANT ACROSS THE STUDY AREA

Substance	Total
Formaldehyde	134.7
Coke oven emissions	61.0
1,3 butadiene	56.5
Carbon tetrachloride	52.1
Chromium	13.5
POM	12.3
Dioxins	12.0
Arsenic	7.4
Beryllium	5.8
Asbestos	5.7
Benzene	5.0
Gasoline vapors	3.0
Cadmium	1.4
Benzo(a)pyrene	0.7
Ethylene dibromide	0.6
Vinyl chloride	0.4
Trichloroethylene	0.3
Perchloroethylene	0.2
PCBs	0.1
Styrene	0.1
All others*	0.1
TOTAL	372.9

*Chloroform, ethylene oxide, acrylonitrile, methylene chloride, chlordane, heptachlor, and epichlorohydrin.

model performance evaluation study suggests that estimates of ISCLT may be less than the estimates of the Climatological Dispersion Model (CDM) under some assumptions by a factor of two or more at receptors roughly 1600 meters downwind. The same study suggests that smaller grid size may increase estimated concentrations predicted at downwind receptors (USEPA/OAQPS, 1989c).

Finally, it should be pointed out that this [redacted]. When air toxic emissions are transported and deposited into waterways or onto land, this phenomenon raises the possibility of incorporation into plants or consumption by animals. As a result, there is a potential for additional carcinogenic risk from air toxics emissions through such pathways as ingestion of fish, soil, crops, surface water, animal milk, mother's milk, and groundwater, and from inhalation through occupational exposures. These potential impacts have not been addressed in this study. In addition, no attempt has been made to evaluate potential differences between indoor and outdoor exposure, or the potential impacts of indoor releases of any of the 57 study pollutants.

Interpretation Of Results - Areawide. As indicated previously, cancer risk at a given location were estimated by multiplying, for each pollutant, the modeled concentration estimate (in $\mu g/m^3$) times the risk per $\mu g/m^3$ of that pollutant, and then summing for all pollutants. These risks are commonly expressed in exponential form where, for example, $2x10^{-5}$ equals 2 chances in 100,000. Thus, a person residing for a lifetime at such a location will have 2 chances in 100,000 of contracting cancer from this exposure.

Incidence is a population-oriented measure of pollutant impact based on excess cancer cases. By multiplying the risk in a given grid times the number of people in that grid, one can estimate a probable number of excess cancer cases contracted as a result of the exposure. For example, if a grid square with an estimated lifetime risk of $2x10^{-5}$ has a population of 100,000, one would estimate that a lifetime of exposure would lead to 2 cancer cases. This figure is sometimes translated to an annual probability: a probability estimate of 4 cases divided by a 70 year lifetime suggests a probability estimate of 4/70 or 0.057 cases per year or one case per 17.5 years. This calculation is done for each grid

square; the total across all grids is then the estimated number of excess cancer cases in the entire study area attributable to toxic air pollution.

The [redacted] or approximately one in ten thousand. Figure 4-1 is a pie chart illustrating the contributions of the various pollutants to this estimated incidence. Figure 4-2 is a pie chart illustrating contributions of various source groupings (as indicated in Table 4-1) for the seven highest contributing pollutants.

As reflected in both Table 4-2 and Figure 4-1, over [redacted] formaldehyde, coke oven emissions, [redacted], carbon tetrachloride, hexavalent chromium, total polynuclear aromatic hydrocarbons (PAHs) expressed as POM, and dioxins. The largest of these is formaldehyde. Most of the formaldehyde incidences are due to the "background" concentrations of formaldehyde due to photochemical generation, i.e., formation of formaldehyde as a result of chemical reactions in an atmospheric mixture of reactive hydrocarbons, nitrogen oxides, and other substances in the presence of sunlight. In most urban ozone nonattainment areas, photochemical processes are controlled primarily by emissions of volatile organic compounds (VOC), most of which are the result of highway mobile sources, industrial facilities, and miscellaneous area sources.

The next largest contributions to total predicted incidences are coke oven emissions, 1-3-butadiene, and carbon tetrachloride. Incidences resulting from these pollutants are all roughly comparable. As with formaldehyde, a mix of sources contribute to these pollutant emissions. Coke oven emissions relate to one specific type of industrial source. 1,3-butadiene is emitted primarily from motor vehicles, and carbon tetrachloride is mainly (though not exclusively) a background pollutant, as a result of previous global carbon tetrachloride emissions.

The next most important contributors are hexavalent chromium, POM, and dioxins. The incidences predicted from these three pollutants are roughly comparable. While chromium comes from a very diverse range of sources, almost half of hexavalent chromium

FIGURE 4-1

ESTIMATED EXCESS 70-YEAR INCIDENCE, AREA WIDE BY POLLUTANT CONTRIBUTION

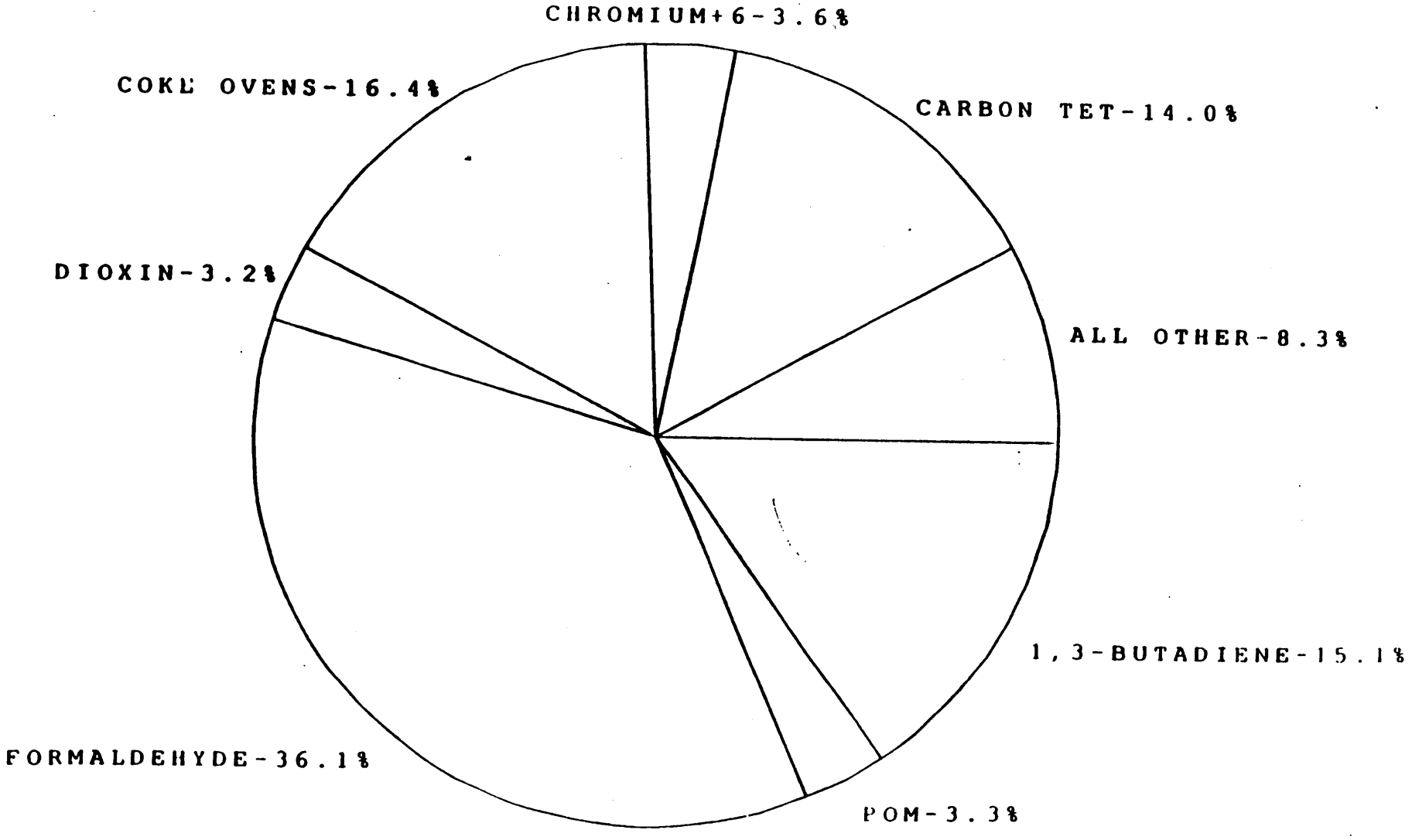
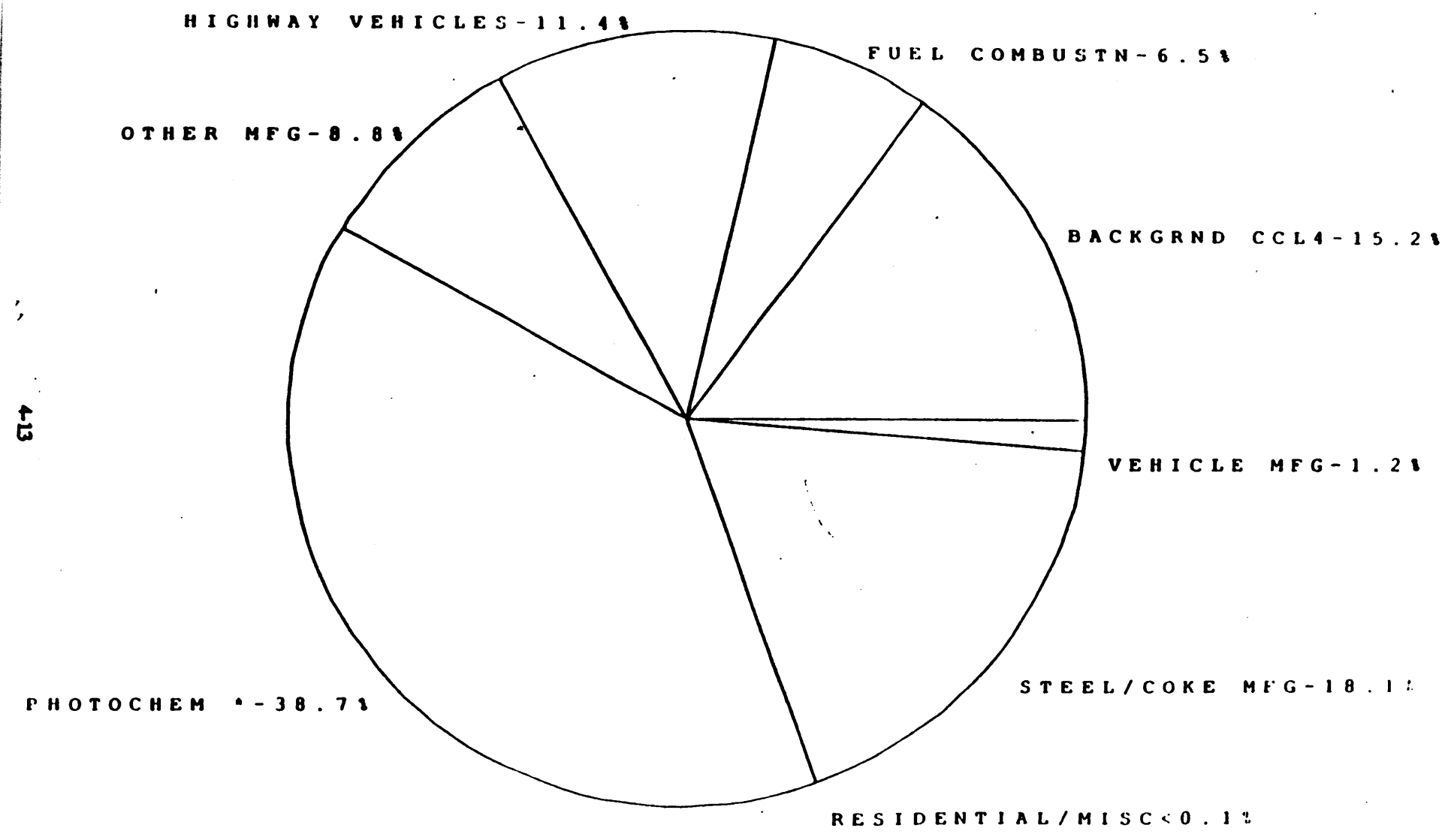


FIGURE 4-2

ESTIMATED EXCESS 70-YEAR INCIDENCE, AREA WIDE BY SOURCE GROUPING CONTRIBUTION



* PHOTOCHEMICAL GENERATION OF FORMALDEHYDE FROM EMISSIONS [illegible] AND MISC. AREA SOURCES

in the Transboundary area comes from chrome plating operations. POM and dioxins come from a variety of fuel combustion sources. The remaining incidences, about 8%, come from a total of the 20 remaining pollutants which have unit risk factors which characterize their carcinogenic potential (see Table 3-2) and which were to determined to be emitted in the Transboundary area (see Table 4-1).

As indicated in Figure 4-2, there are significant contributions to every major source grouping except residential and miscellaneous area sources (which contribute less than 0.1% to the total incidences). The split among source groupings is relatively even. Nevertheless, several observations can be made. First, the four largest categories are photochemical generation of formaldehyde, steel and coke manufacturing, background carbon tetrachloride, and highway vehicles. Second, if photochemical formaldehyde were evaluated in terms of its potential source contributions, the relative proportions of contributions from source categories which are major VOC emitters (highway vehicles, vehicle manufacturing, and other industry) would be substantially enlarged. It should be pointed out that the direct incidence contribution of motor vehicle manufacturing facilities, a leading industry in the region, is relatively low. Finally, a substantial portion of the fuel combustion incidences are the result of dioxin, which are in turn the result of one source, the Detroit incinerator.

Figures 4-3 and 4-4 portray the geographic location of cancer incidence and individual risks. Total incidences in a particular grid cell may be misleading, because in this study individual grid cell size varied. Therefore, results are presented in units of incidence per square kilometer. Portraying incidences per square kilometer is more significant because it eliminates cell size from affecting the results.

Even given this approach, the highest total incidences are concentrated in the core area, where the cell size is the smallest. To a much smaller extent, there is a concentrated incidence area around the Port Huron/Sarnia area. Incidence concentrations, especially in the core area, are the result of the relative geographic proximity of sources and population. Clearly, population density is a very important consideration because of the opportunity for greater exposure. Contributions to total incidences in the outer parts of the study area are rather low, but build up rapidly towards peaks in the study area. The differences between the low risk and the high risk areas as shown in Figure 4-4, are less dramatic than the

FIGURE 4-3

ESTIMATED EXCESS 70-YEAR INCIDENCE PER SQUARE KILOMETER

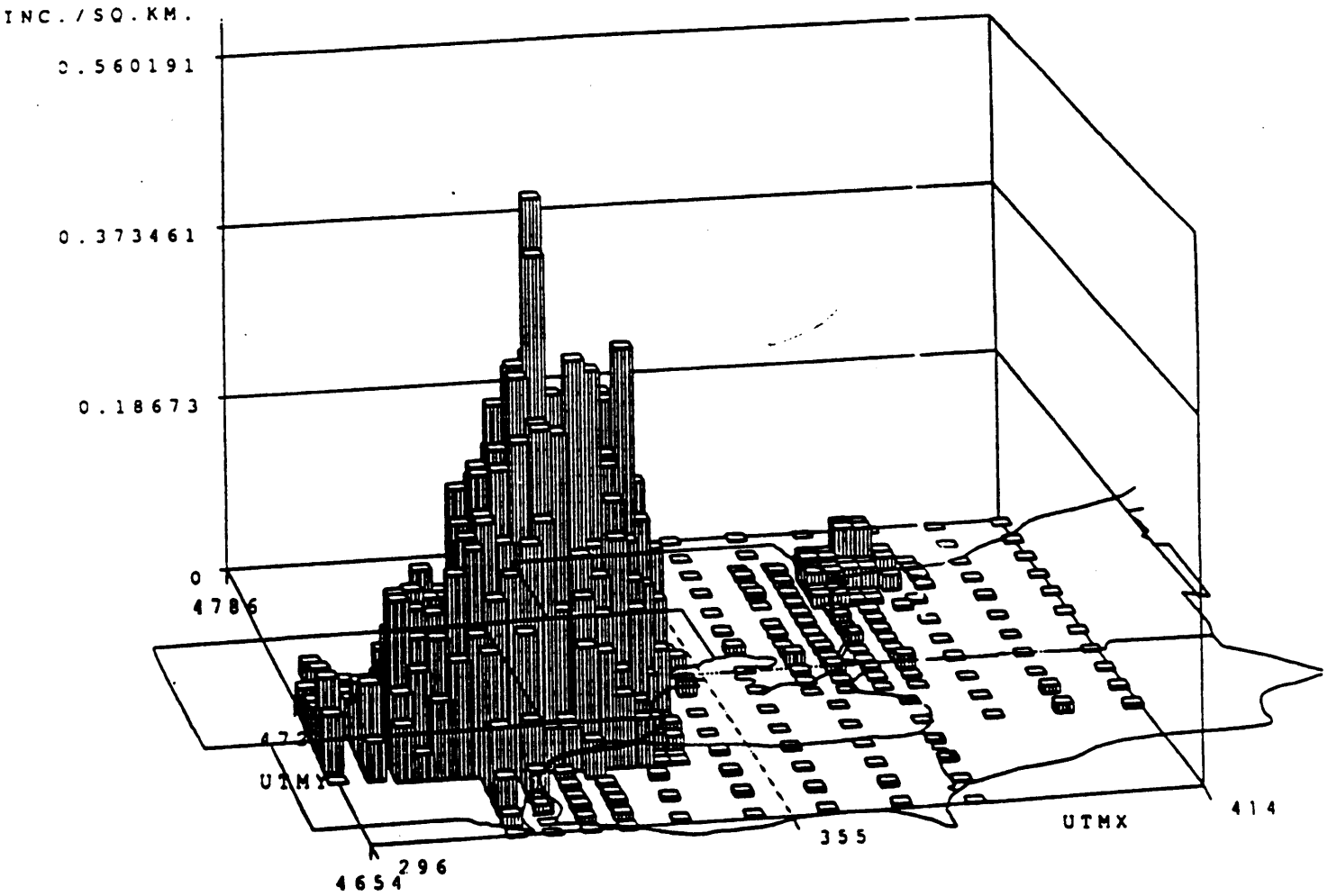
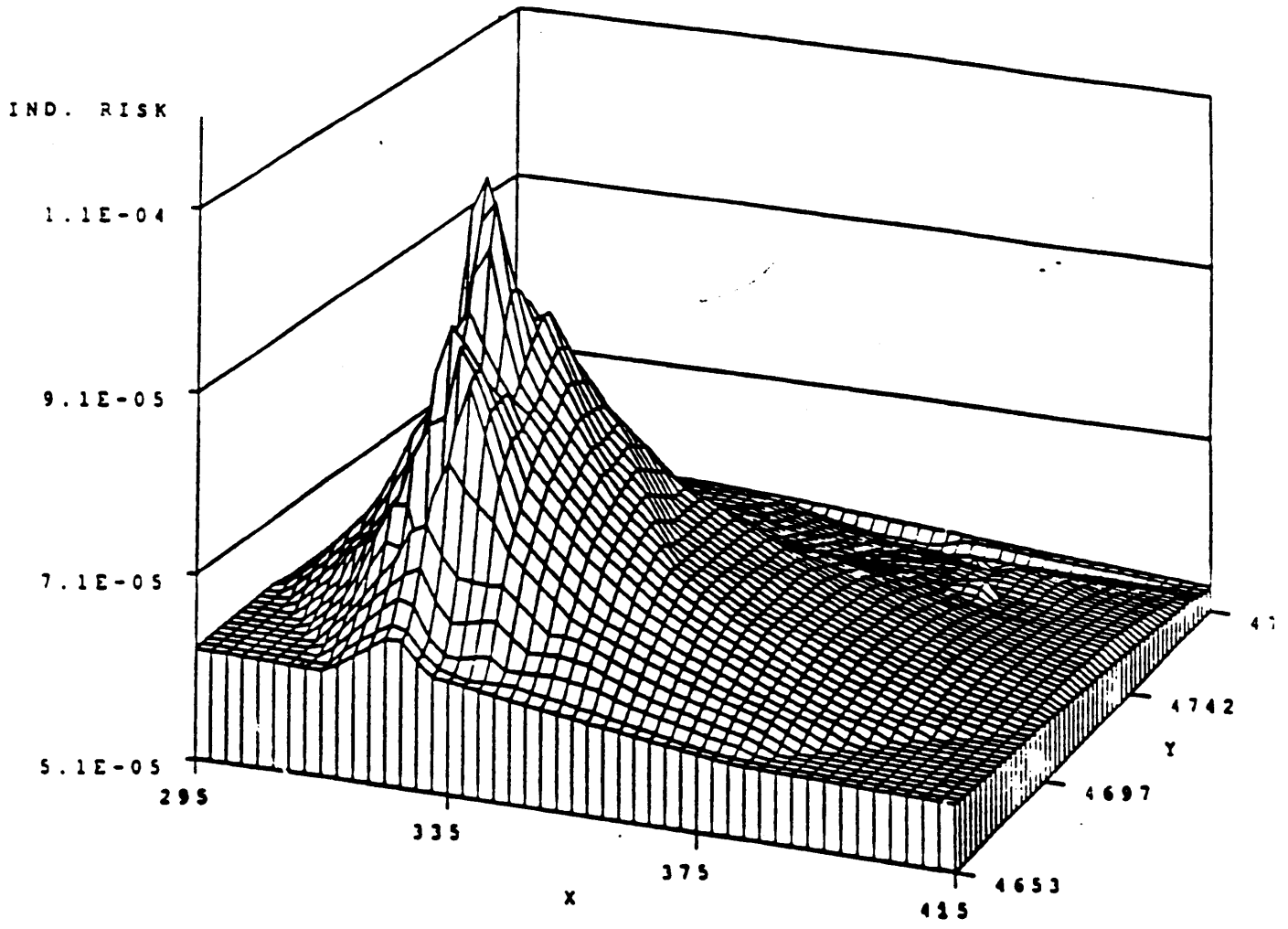


FIGURE 4-4

ESTIMATED EXCESS 70-YEAR
INDIVIDUAL RISK



differences between low incidence and high incidence areas shown in Figure 4-3. This differentiation between the two figures reflects the effect of differing population densities in the study area.

Interpretation of Results - Core Area. The core area of the study area is located astride the U.S. - Canadian border, and includes Detroit, most of the industrial area in Windsor and Wayne County, and parts of Macomb and Oakland Counties. It includes all of the 2 1/2 km grid cells not in Pt. Huron and Sarnia. As indicated in Figures 4-3 and 4-4, the peak risks and incidences are located in the core area. This is not unexpected because of the proximity of emissions and population. Figure 4-5 shows the locations of the grid cells with the peak risks and incidences on the U.S. and Canadian sides.

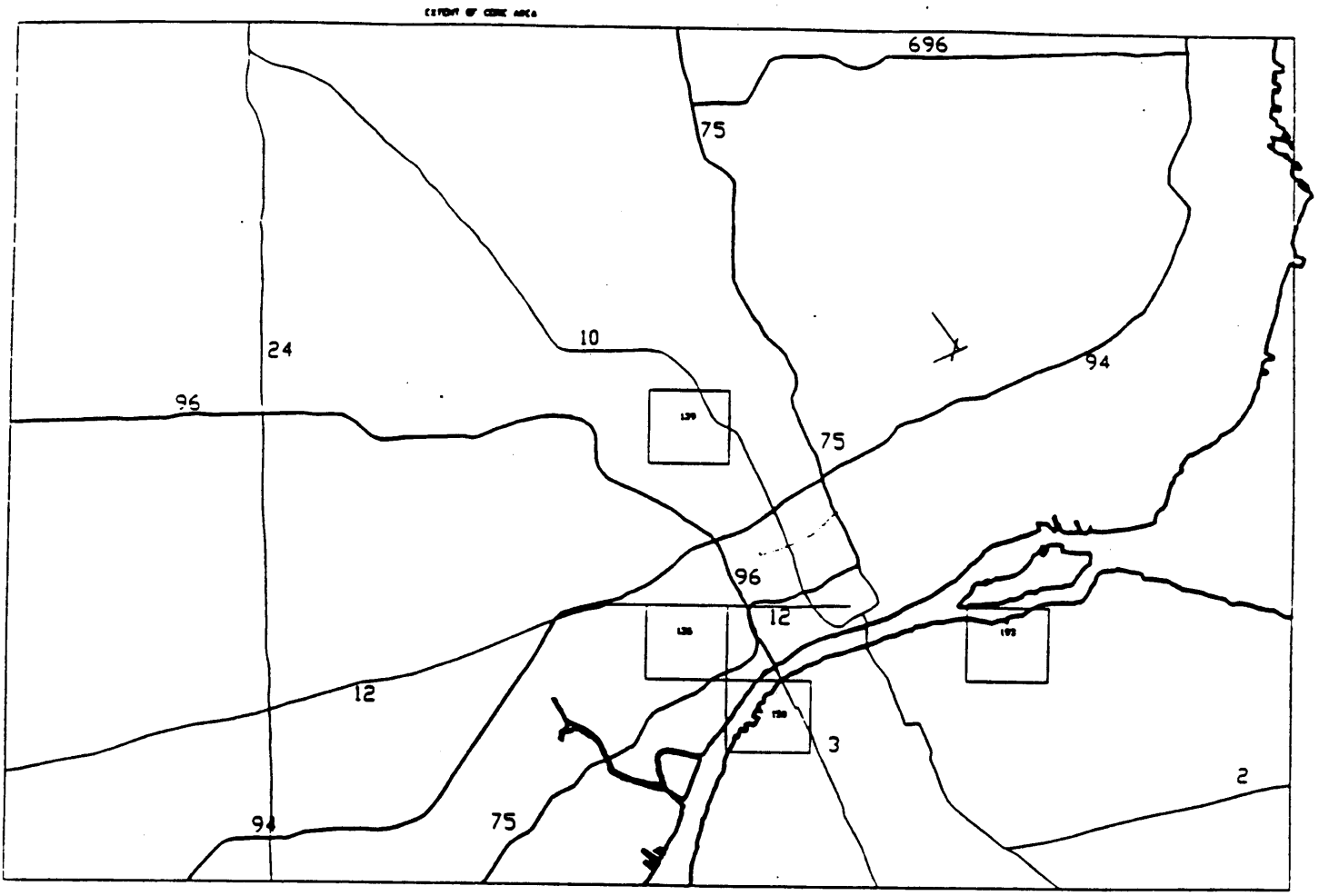
Figures 4-6, 4-7, and 4-8 present population, incidence per square kilometer, and individual risk for the grid cells within the core area. As can be seen in Figure 4-6, population is most concentrated in the northern half of the core area (on the U.S. side). Figure 4-7 provides a portrayal of the peaks that were shown in the three-dimensional presentation in Figure 4-3.

Figure 4-8 highlights those areas with highest individual risk. The two cells with a risk in excess of 1.2×10^{-4} are cells 136 and 150. Cell 136 is the cell in the north central area with the greatest overall contribution from coke oven emissions (over 40%). Cell 150 has similar proportional impact from coke oven emissions, but total incidences in this particular cell are limited; this cell is located over the Detroit River, and there is a relatively small population located on the limited land area of Detroit and Windsor within its boundaries.

Tables 4-3 and 4-4 provide a presentation of the contributions by pollutant and source groupings to the risks in grid cell 136, the peak risk area. These tables both show the relative dominance of coke oven emissions versus other pollutants and sources at this site. (As with the previous figures, the source grouping data in Table 4-4 is based on the top seven contributing pollutants areawide.) Calculations for grid cell 150 show very similar results for both pollutant and source grouping contributions.

FIGURE 4-5

GRID CELLS FOR THE 2.5 X 2.5 KM AREA



GRID CELL	SITE
139	U.S. Area of Highest Incidence
193	Canadian Area of Highest Incidence
136	Peak Individual Risk Area
150	Peak Individual Risk Area

-Individual risks at grid cells 136 and 150 are nearly equivalent.
-Incidences at highest U.S. girds are substantially higher than at highest Canadian girds.

FIGURE 4-6

POPULATION BY GRID CELL IN THE CORE AREA

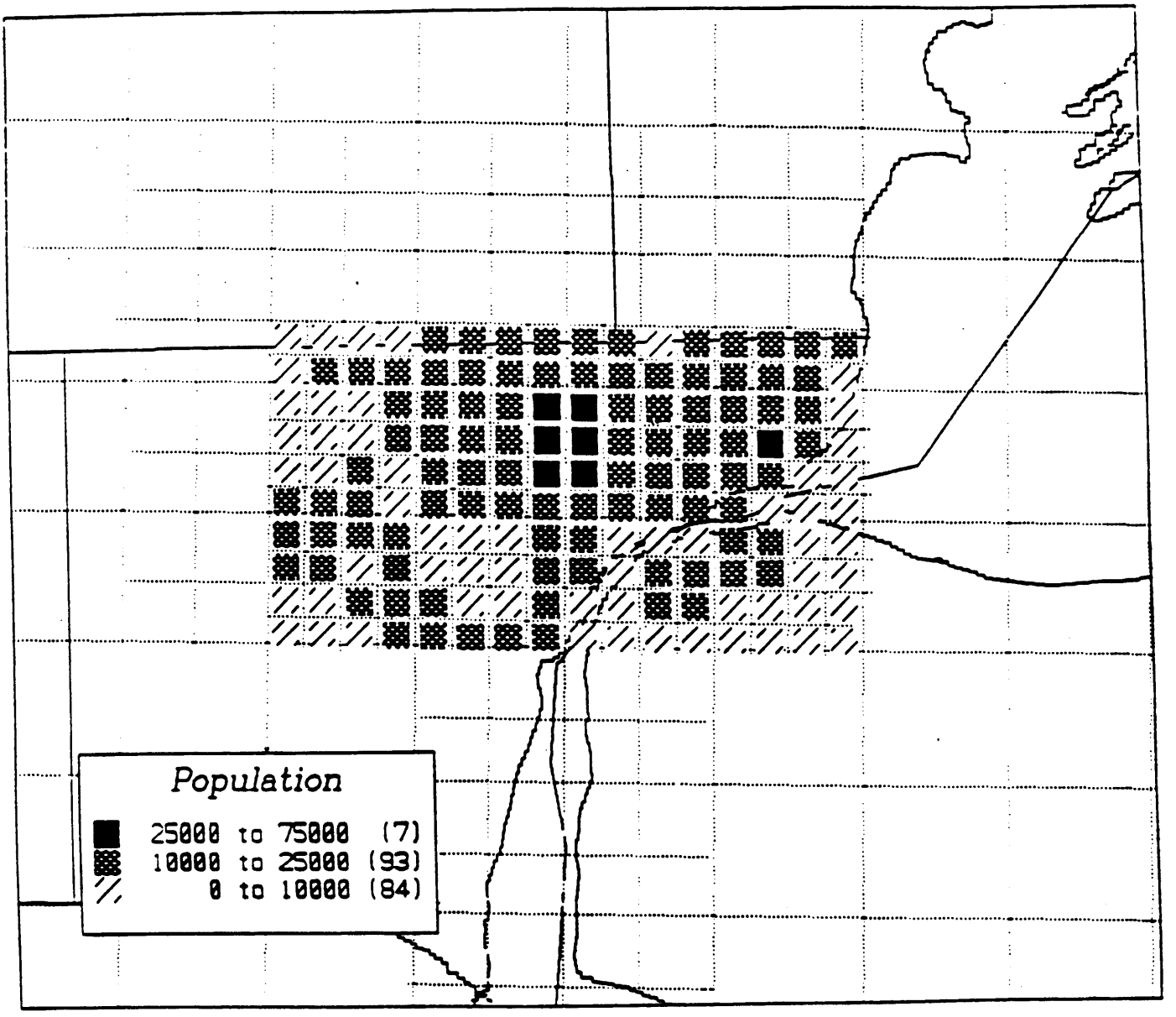


FIGURE 4-7

INCIDENCE PER SQUARE KILOMETER
BY GRID CELL IN THE CORE AREA

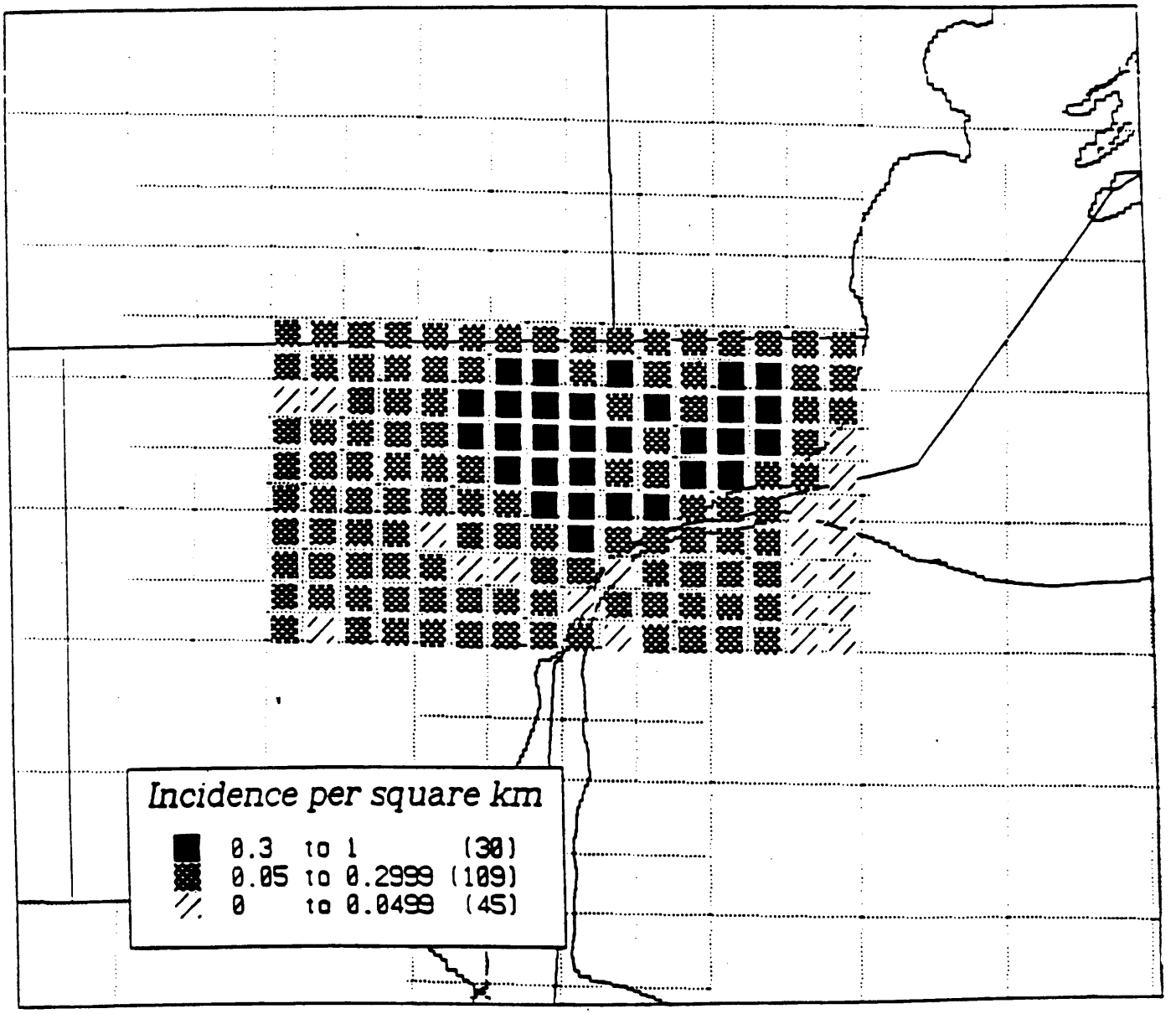


FIGURE 4-8

INDIVIDUAL RISK BY GRID CELL
IN THE CORE AREA

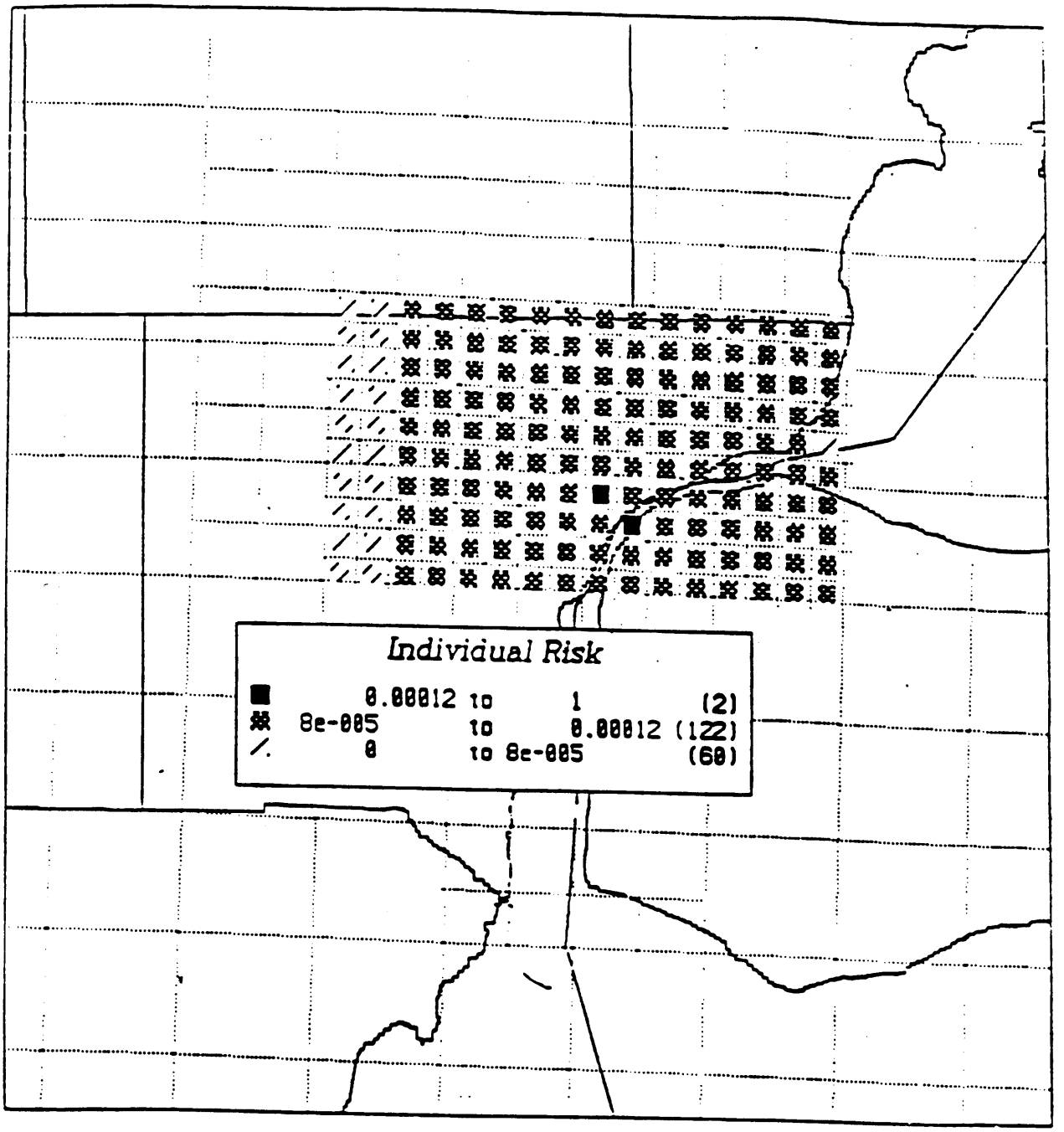


TABLE 4-3

POLLUTANT CONTRIBUTION TO RISK AT GRID CELL WITH HIGHEST INDIVIDUAL RISK*

Pollutant	%
Coke oven emissions	37.4
Formaldehyde	24.6
1,3 butadiene	11.9
Carbon tetrachloride	9.4
Arsenic	2.8
Chromium	2.6
POM	2.6
Dioxins	2.6
Beryllium	2.0
Asbestos	1.3
Benzene	1.2
Gasoline vapors	0.6
Cadmium	0.5
Benzo(a)pyrene	0.1
Ethylene dibromide	0.1
Vinyl chloride	0.1
Trichloroethylene	0.1
Others**	0.1
TOTAL	100.0

*Grid Cell 136.

**Perchloroethylene, PCBs, chloroform, styrene, acrylonitrile, ethylene oxide, methylene chloride, chlordane, heptachlor, and epichlorohydrin.

TABLE 4-4

SOURCE GROUPING CONTRIBUTION TO GRID CELL WITH HIGHEST INDIVIDUAL RISK*

Source Grouping**	%
Steel and coke manufacturing	40.5
Photochemically generated formaldehyde	26.8
Background carbontetrachloride	10.6
Highway vehicles	9.1
Other industry	6.8
Fuel combustion	5.1
Vehicle manufacturing	1.1
TOTAL	100.0

*Grid cell 136.
**Residential and miscellaneous sources contribute less than 0.1%.

Interpretation of Results - U.S. Area of Highest Incidence. The area of highest incidence on the U.S. side of the border is in central Detroit, about seven kilometers (between four and four and a half miles) northwest of downtown Detroit. The contributions to cancer incidence at this location are relatively similar to the results for the study area as a whole. Figure 4-9 shows the relative pollutant contribution for the seven top pollutants - formaldehyde, coke oven emissions, carbon tetrachloride, 1,3-butadiene, hexavalent chromium, dioxin, and polycyclic organic matter with all other pollutants grouped together. As with the relative pollutant contribution areawide, the seven top pollutants contribute to the majority of total incidences - about 96% compared to a total of roughly 92% over the area as a whole.

Figure 4-10 shows the relative source group contribution for this area for the top seven pollutants. Of those pollutants that contribute at least one cancer incidence, arsenic, beryllium, and cadmium are all point source dominated, with fuel combustion being the major contributor; arsenic, beryllium, and cadmium are all trace contaminants which are emitted during combustion of coal and fuel oil. In contrast, the emissions of asbestos, benzene, and gasoline vapor are primarily from motor vehicles, though nearly a third of benzene comes from point sources such as petroleum product storage and marketing. ("Gasoline vapors" only include emissions from vehicle refueling.)

The major difference between Figures 4-1 and 4-2 (pollutant and source category contributions) for the area as a whole and Figures 4-9 and 4-10 for the highest U.S. incidence area is the role of steel and coke manufacturing and specifically, coke oven emissions. The contribution of coke ovens is substantially greater at the highest incidence site than for the area as a whole.

Another significant conclusion is the relative risks on the U.S. versus the Canadian side of the border. As Figures 4-3 and 4-4 show, the peak individual risks as well as the relative incidences per square kilometer are much greater on the U.S. side of the border. There are in fact dozens of grid cells on the U.S. side with incidences per square kilometer greater than the highest incidence area on the Canadian side. The next section discusses the results of the analysis done on the peak Canadian area of highest incidence.

FIGURE 4-9

CONTRIBUTION TO ESTIMATED RISK AT U.S. GRID CELL WITH HIGHEST INCIDENCE, BY POLLUTANT

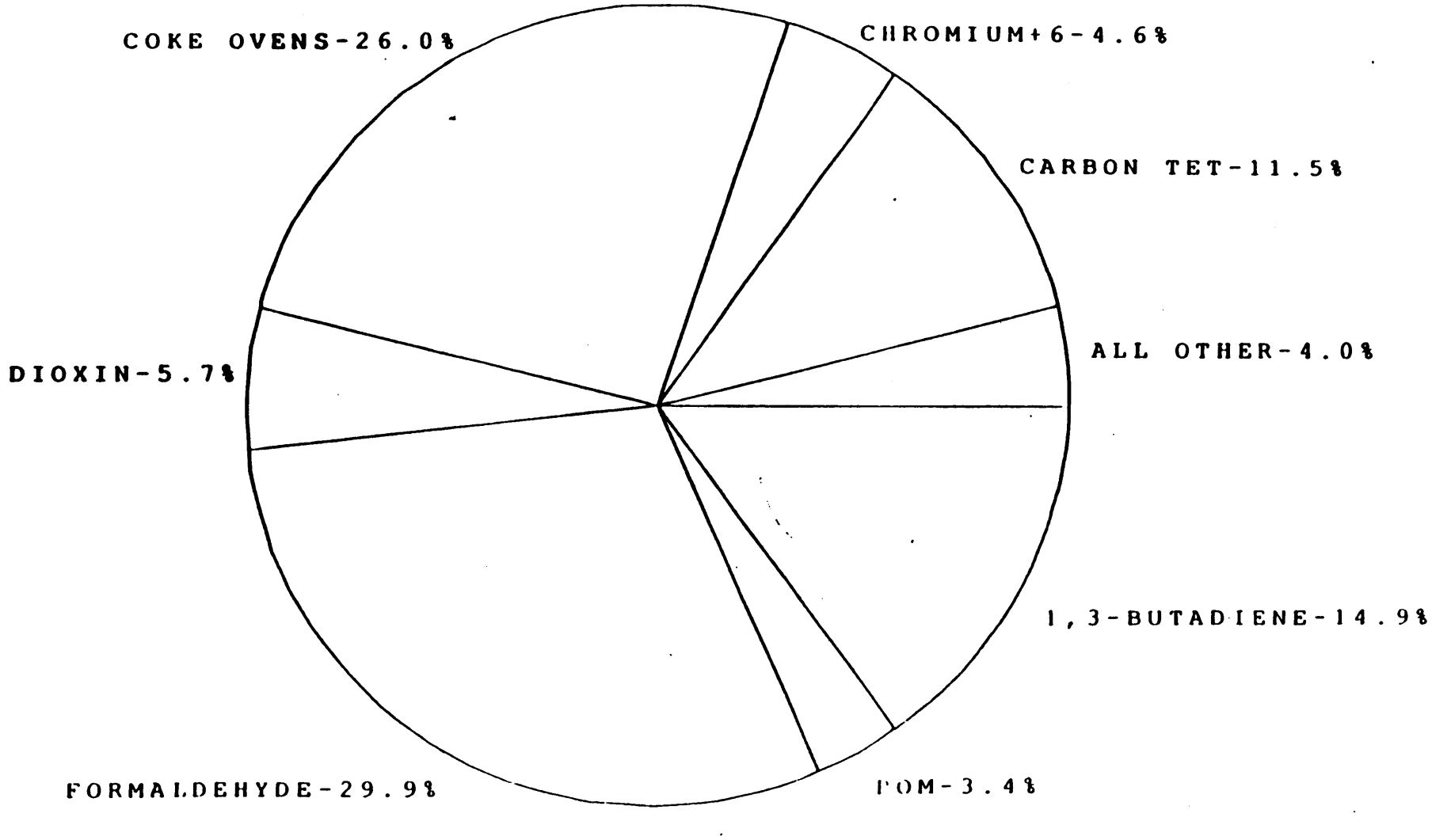
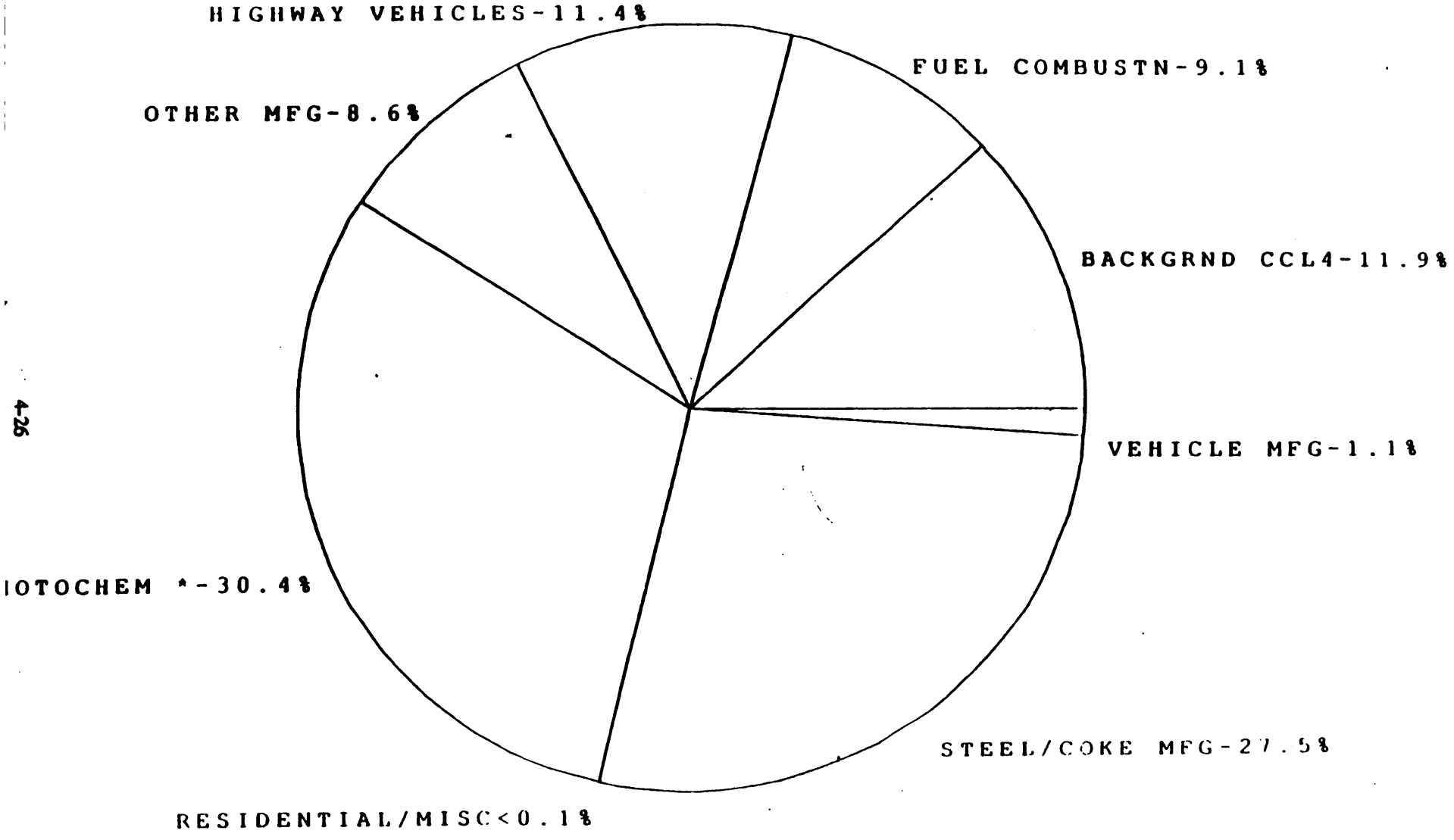


FIGURE 4-10

CONTRIBUTION TO ESTIMATED RISK AT U.S. GRID CELL WITH HIGHEST INCIDENCE, BY SOURCE GROUPING



* PHOTOCHEMICAL GENERATION OF FORMALDEHYDE FROM EMISSIONS FROM VEHICLES, INDUSTRIAL FACILITIES, AND MISC. AREA SOURCES

Interpretation of Results - Canadian Area of Highest Incidence. The area of highest incidence on the Canadian side of the border is in Windsor, approximately four and a half kilometers (a little less than three miles) southeast of downtown Detroit. Figures 4-11 and 4-12 show the results of pollutant and source grouping analyses for the area. The results are very similar to those for the U.S. side. Again, the major differences with the areawide results is that there is a substantially higher contribution from steel and coke manufacturing (i.e., coke oven emissions) than for the areawide results. The primary difference between the areas of highest incidences on the Canadian U.S. sides is that the risk and relative incidences on the Canadian side (and, for that matter, Canadian grid cells as a whole) are substantially lower.

The reason for this disparity is that incidences tend to be concentrated where emissions and population are in close proximity. In the case of the Transboundary study area, emissions and population are concentrated on the U.S. side, especially in the core area. Out of a total population of 4,285,000 in the study area, about half a million reside on the Canadian side of the border. Similarly, the carcinogenic pollutants (those with unit risk factors) are primarily, though not exclusively, emitted on the U.S. side. Carcinogenic pollutants are also emitted on the Canadian side, but the combination of a smaller proportion of total industrial sources and a smaller population contribute to a substantially smaller total of incidences.

CONCLUSIONS

The risk estimates presented in this report should be regarded as only rough approximations of total cancer cases and individual lifetime risks, and are best used in a relative sense. Estimates for individual pollutants are highly uncertain and should be used with particular caution. More detailed discussions of the uncertainties are included in the respective individual sections presented above.

This project found atmospheric emission of 27 pollutants in the study area which USEPA considers carcinogenic, out of the original total of 57 pollutants; some of these pollutants have been shown to be carcinogenic based on human exposure data, and others have been implicated by animal studies. Emissions of fifteen additional pollutants (which USEPA does not consider to be carcinogenic, or for which there is insufficient information

FIGURE 4-11

CONTRIBUTION TO ESTIMATED RISK AT CANADIAN GRID CELL WITH HIGHEST INCIDENCE, BY POLLUTANT

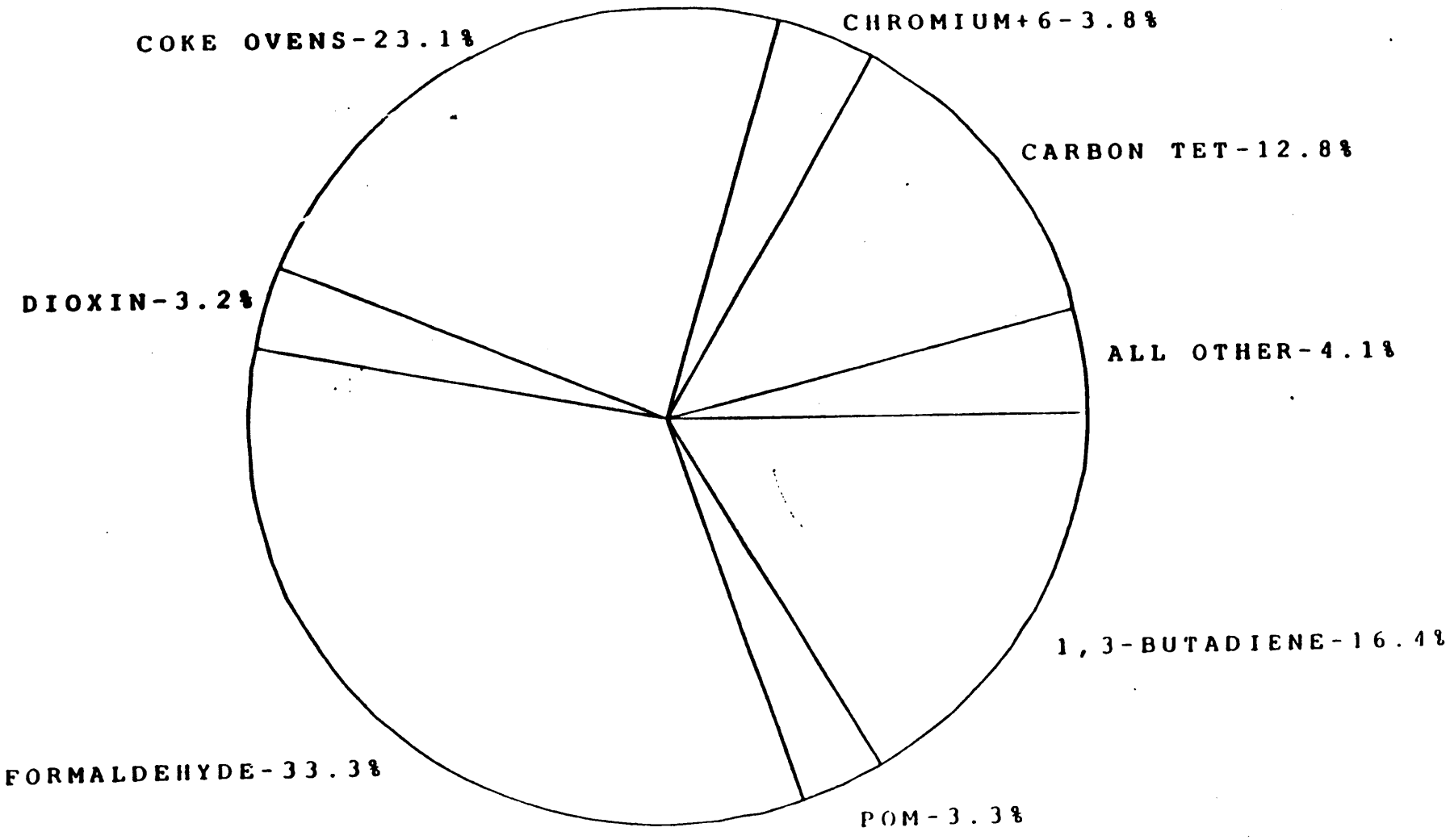
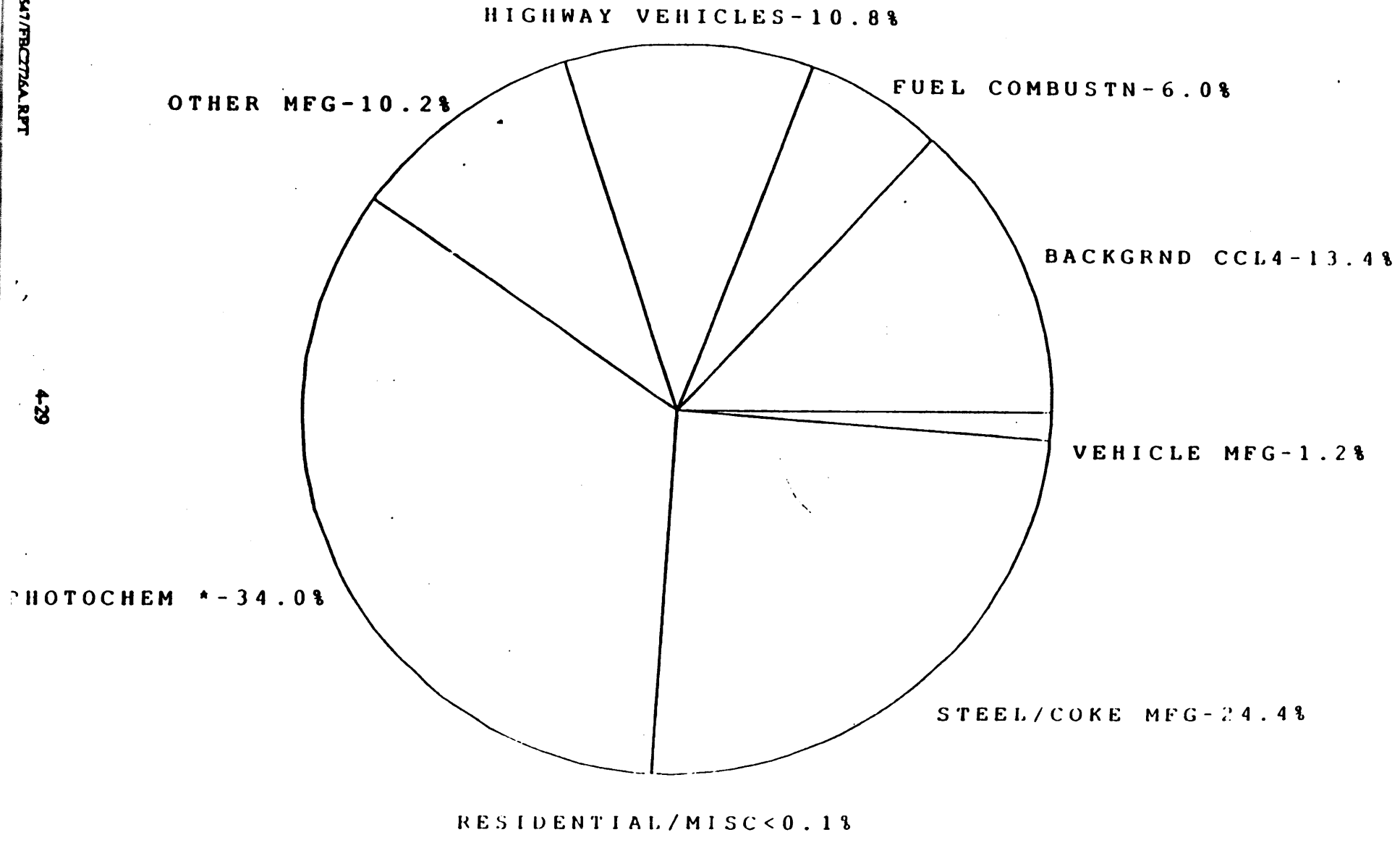


FIGURE 4-12

CONTRIBUTION TO ESTIMATED RISK AT CANADIAN GRID CELL WITH HIGHEST INCIDENCE, BY SOURCE GROUPING



* PHOTOCHEMICAL GENERATION OF FORMALDEHYDE FROM EMISSIONS

for USEPA to judge carcinogenicity) were also found to be emitted in the area. This study suggests that about 373 cases of cancer over 70 years, or about 5 cancer cases attributable to air pollution per year in this study area. Further, a peak lifetime risk of [redacted] is estimated in the study area. There is some geographic variability in the risks across the study area. In general, risks are greatest in south central Detroit, near the area's coke ovens. [redacted]

In evaluating the sources of airborne risk in this area, about [redacted] are due to photochemically generated formaldehyde, as a result of emissions from motor vehicles, industrial facilities, and miscellaneous area sources. The most significant direct contributor was steel and coke manufacturing facilities with about 18% of total incidences. Background carbon tetrachloride (about 15%), highway vehicles (about 11%), other industrial facilities (about 9%), and fuel combustion (about 7%) were the next most significant categories. The least significant categories were vehicle manufacturing (about 1%) and residential and other miscellaneous area sources (nearly zero). However, vehicle manufacturing facilities (especially painting and degreasing activities) can emit significant volatile organic compound emissions which can contribute to photochemical generation of formaldehyde and other substances.

It is useful to apportion the estimated total number of cancer cases according to the weight of evidence that the pollutants are carcinogenic. According to USEPA's review of the weight of evidence of carcinogenicity the 27 pollutants for which risks were estimated in this study include "known human carcinogens," "probable human carcinogens "and "possible human carcinogens." Of the estimated 373 cancer cases per 70 years, about 25% are attributable to "known human carcinogens," and about 75% are attributable to "probable human carcinogens." No cases are attributable to "possible human carcinogens."

To put the air toxics risk in perspective, it would be desirable to discuss cancer risks due to other forms of environmental pollution. However, this study focused on air pollution risks and did not evaluate risks from other forms of exposure to environmental contamination. Other exposure routes include exposure through drinking water, skin contact, eating fish or swimming in lakes (e.g., Lake St. Clair) which may contain contaminants, and exposure to indoor air contaminants including radon. Also complicating

any review of the relative significance of air pollution is the potential for other air pollutants which cannot currently be quantitatively evaluated but nevertheless cause significant risks. Air pollution appears to be an important cause of environmental pollution-related cancer cases in this area, but a comparison of airborne risks to risks from other environmental exposures is outside the scope of this study.

Although specific estimates of individual risks and area-wide cancer cases have been given in this report, the uncertainties underlying these estimates dictate that these estimates be used cautiously. The specific types of uncertainty inherent in these estimates have been described in various sections of the report, and include various uncertainties in estimating emissions, uncertainty in quantifying atmospheric dispersion, and various uncertainties in developing until risk factors from available human or animal data. In addition, concentrations in this study may generally be understated, whereas unit risk factors are designed to be more likely to overstate than to understate risks. Thus, this study may either overstate or understate risks, and in either case may provide estimates which differ substantially from the actual risks.

In interpreting this data, it should be noted that a number of similar studies (e.g. Summerhays, 1989) show individual risks higher than the individual risks illustrated in this study. However, it should be pointed out that the methodologies, including the dispersion models and modeling protocols, do differ between this study and other studies. Therefore, it is difficult to compare directly the results of this study with other studies, and make conclusions about the comparative risks of the Transboundary area with other areas. In addition, it should be noted that using the protocol and modeling grid chosen may not reveal the peak individual risk or its exact location. Modeling receptors were placed at the centroids of the grid cells, and therefore, if a higher risk point were located between receptors, it would not be detected. A more thorough modeling analysis of all emission points within facilities of particular interest with multiple receptors (within high risk grid cells) would provide a higher probability for locating particularly high risk areas.

This study was designed as a screening study of a broad range of source types and air pollutants, rather than as a more intensive study of any single source type or pollutant. As such, more reliable results could be obtained by further investigation of several

elements of the study. Given the evolving nature of knowledge for the pollutants in this study, a new review of the literature would likely suggest several modifications in the emissions estimates used in the study.

CHAPTER 5

DEPOSITION ASSESSMENT

The deposition assessment used the same emission inventory, grid system, and model (ISCLT) as the risk assessment. This chapter reviews both the approach used for deposition modeling and the results.

DEPOSITION MODELING APPROACH

Deposition Processes and Implications for Modeling in this Study

Atmospheric deposition processes depend on a complex interaction of atmospheric chemistry and transport phenomena. Different substances may occur in different phases, and a single substance may occur in more than one phase simultaneously. In fact, within a region (such as the Transboundary area) it is quite likely that many pollutants will be split among several environmental compartments (soil, suspended particles, vapor phase atmosphere, surface water, etc.), with a dynamic exchange of material between compartments (Thibodeaux, 1979).

Deposition processes include gravitational settling of particles, dry deposition of gases and particles, and wet deposition of gases and particles. The key measure of deposition rates for these three mechanisms are settling velocity, dry deposition velocity (sometimes referred to as just "deposition velocity"), and washout ratio. Settling velocity describes the average rate at which relatively large particles settle to the surface; as the diameter of particles decrease, particles tend to stay suspended (i.e., settling velocity goes to zero). In contract, deposition velocity is a measure of the flux of a suspended particle or gas towards the surface through other transport mechanisms. A washout ratio is the concentration of a substance in precipitation divided by the concentration of the same substance in the atmosphere immediately prior to precipitation. Therefore, solubility in water and the relative split of a substance between an aqueous medium and an atmospheric medium (as expressed by a substance's Henry's Law constant) will in large part determine a

substance's washout ratio. Theoretically, if the concentration and the washout ratio is known, wet deposition can be estimated if the precipitation rate is known.

The purpose of this analysis is to provide a screening level estimate of deposition into the Great Lakes watershed. As an approximation of the impacts, it was decided to focus on those grid cells which include or touch the major Great Lakes waterways (Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, and Lake Erie). In total, 102 grid cells were identified. Deposition modeling therefore needed to be organized using the emissions database developed with procedures described above, and focused on the 102 waterway cells.

Developing inputs for detailed deposition modeling is far from straightforward. Deposition velocities and washout ratios have been empirically measured, both in the laboratory and in the field, but there are no standardized values for different types of substances. While some empirical data is available (some of which is discussed below), in some cases results may vary by an order of magnitude. It was therefore decided to develop a number of different scenarios in order to reflect the range of pollutant behavior, and the uncertainty implied by the documented empirical data.

Deposition scenarios were defined by ISCLT inputs. While ISCLT covers dry deposition processes, it accepts only specification of a settling velocity (for larger particles) and a reflection coefficient to describe deposition behavior. (The reflection coefficient expresses the proportion of a substance which is "reflected" when it comes in contact with the surface.) Therefore, because it was desired to estimate a reasonable range of deposition rates for individual pollutants, it was necessary to first develop a reasonable range of settling velocities/reflection coefficient combinations.

Particle settling velocities are a function of particle size, with smaller particles having slower velocities. Gases do not have settling velocities as such, so for the purposes of this analysis, it was assumed that gases would behave as if they were small particles. Small particle settling velocity (with a typical reflection coefficient for small particles) was therefore taken as the basic assumption for assumed "low deposition" scenario. A large

particle settling velocity (with a typical reflection coefficient for large particles) was taken as the basic assumption for a "high deposition" scenario.

There is substantial data available on settling velocities of particles. Based on published summaries (McMahon and Denison, 1979, and Sehmel, 1980), 0.05 cm/sec is a representative terminal settling velocity for smaller particles (less than 10 microns), while 1 cm/sec is representative for larger particles. Based on Figure 2.8 of the ISC *User's Guide* (USEPA/OAQPS, 1986b), reflection coefficiencies should be in the range of 0.95 for a 0.05 cm/sec settling velocity, and 0.75-0.80 for a 1 cm/sec settling velocity.

ISCLT however only addresses dry deposition processes; it has no algorithm for wet deposition. Both gases and particles may be subject to wet deposition, but the relative relationship of wet to dry deposition may be dependent on a number of variables, including the tendency of a substance to sorb onto suspended particles, its solubility in water, and other factors. In some areas, such as California where rainfall is less than the eastern United States and Canada, dry deposition appears to be the primary toxics deposition mechanism (California Air Resources Board, 1987). However, much of the work in the Great Lakes area indicates that wet deposition is just as important, and probably more important, than dry deposition.

For example, Swackhamer et al. reported that at a remote lake in Isle Royale, Michigan, wet deposition of PCBs was three times dry deposition of PCBs (Swackhamer et al., 1988). Strachan and Eisenreich reported a 1.3 wet-to-dry ratio for PCBs (Strachan and Eisenreich, 1987). Eisenreich et al. reported a wet-to-dry ratio of 1.5-5.0 for a variety of high molecular weight organics, including several of the polynuclear aromatic hydrocarbons (PAH) on the study list of 57 pollutants. Scudlark and Church calculated a wet-to-dry ratio for arsenic on the Delaware coast of 2.4 (Scudlark and Church, 1988). However, it must be pointed that empirical data does vary widely. Some pollutants, such as gases with high Henry's Law constants for example, will be less susceptible to wet deposition processes.

For the purposes of comparison then, two alternative calculations were set up, using dry deposition rates as a base (low and high scenarios). A factor of three was assumed to be a generally applicable wet-to-dry ratio. A lower bound for wet deposition was set at 30

percent of dry deposition to account for those pollutants which are less susceptible to wet deposition processes. This factor was chosen to give an order of magnitude range from the "high" estimate of wet deposition (i.e., three times dry deposition).

Modeling Inputs and Calculation of Total Deposition Rates

The discussion outlines an approach based on two dry deposition scenarios a "low deposition" rate scenario and a "high deposition" rate scenario. ISCLT was therefore run twice, once for each scenario. All model inputs were the same as for dispersion modeling runs (see section on the dispersion modeling approach), except that deposition was not set to zero. As with the dispersion modeling runs, a "unit" emission rate was used, and receptors were located at the centroids of grid cells. Total annual deposition rates were then calculated by summing the products of unit source-receptor deposition contributions at individual receptors times source strengths of the individual sources. Total deposition over a grid cell was then determined by multiplying the total deposition rate by the surface area of the cell.

The next step was to classify pollutants according to deposition scenario (low or high). Sehmel suggests that dry deposition rates of gases can be in an order of magnitude lower than dry deposition rates on particles (Sehmel, 1980). Therefore, pollutants which can be classified as primarily vapor phase pollutants were assigned to the "low" scenario; those which can be classified as primarily particle-based were assigned to the "high" scenario. A summary is provided in Table 5-1. Several of the gaseous pollutants are very volatile and nearly insoluble in water. These are noted in Table 5-1.

This table was organized based on engineering and scientific judgment using a number of basic references (Howard, 1989, Howard, 1990, Rice, 1982, Green, 1984, and Weast, 1967). Because of conflicting and/or ambiguous information, five pollutants were analyzed for both scenarios. It should be noted that few if any of these 42 pollutants can be classified as purely a vapor phase or a particle-based pollutant.

TABLE 5-1

SUMMARY OF POLLUTANT BY DEPOSITION SCENARIO

Low Deposition Scenario	High Deposition Scenario
Acrylonitrile	Arsenic
Allyl chloride*	Asbestos
Benzene	Beryllium
1.3 butadiene*	Benzo(a)pyrene
Carbon tetrachloride*	Cadmium
Chloroform*	Chlordane
Epichlorohydrin	Chromium
Ethylene dibromide	Chrysene
Ethylene dichloride	Coke oven emissions
Ethylene oxide	Diazinon
Formaldehyde	Dioxins
Gasoline vapors	Fluoranthene
Methylene chloride	Furans
Perchloroethylene	Guthion
Trichloroethylene	Heptachlor
Vinyl chloride*	Lead
	Methyl chrysenes
	Nickel
	Parathion
	Selenium
	Total PAHs

Both Scenarios

Di n-butyl phthalate
Mercury
Phenanthrene
Polychlorinated Biphenyls
Styrene

* Very volatile and insoluble in water

Wet deposition rates were then calculated as follows:

Low Deposition (volatile/insoluble) - Because of the chemical properties of these four pollutants, it was assumed that they are resistant to wet deposition processes, and wet deposition was assumed to be equal to zero.

Low Deposition (others) - Wet deposition ranges from 30 percent to three times the low dry deposition estimate.

High Deposition - Wet deposition ranges from 30 percent to three times the high dry deposition estimate.

Both Scenarios - Wet deposition ranges from 30 percent of the low dry deposition estimate to three times the high dry deposition estimate.

Total deposition rate was then calculated by a simple addition of the dry deposition rate to the wet deposition rate. The full methodology is presented in Figure 5-1. As mentioned above, the total deposition per cell was calculated by multiplying the total deposition rate by the surface area.

SUMMARY OF RESULTS

Table 5-2 provides a summary of deposition results using the methodology described above. Estimates are provided for the same 42 pollutants for which emission estimates were provided. Ranges are provided for all pollutants, except for the five which were designated as "dry deposition only" pollutants. Due to the screening nature of this assessment and the uncertainty associated with a number of assumptions, all results were rounded to one significant figure. Unlike the risk assessment analysis in Chapter 4, chromium results are for total chromium, not hexavalent chromium.

FIGURE 5-1

SUMMARY OF DEPOSITION CALCULATION METHODOLOGY

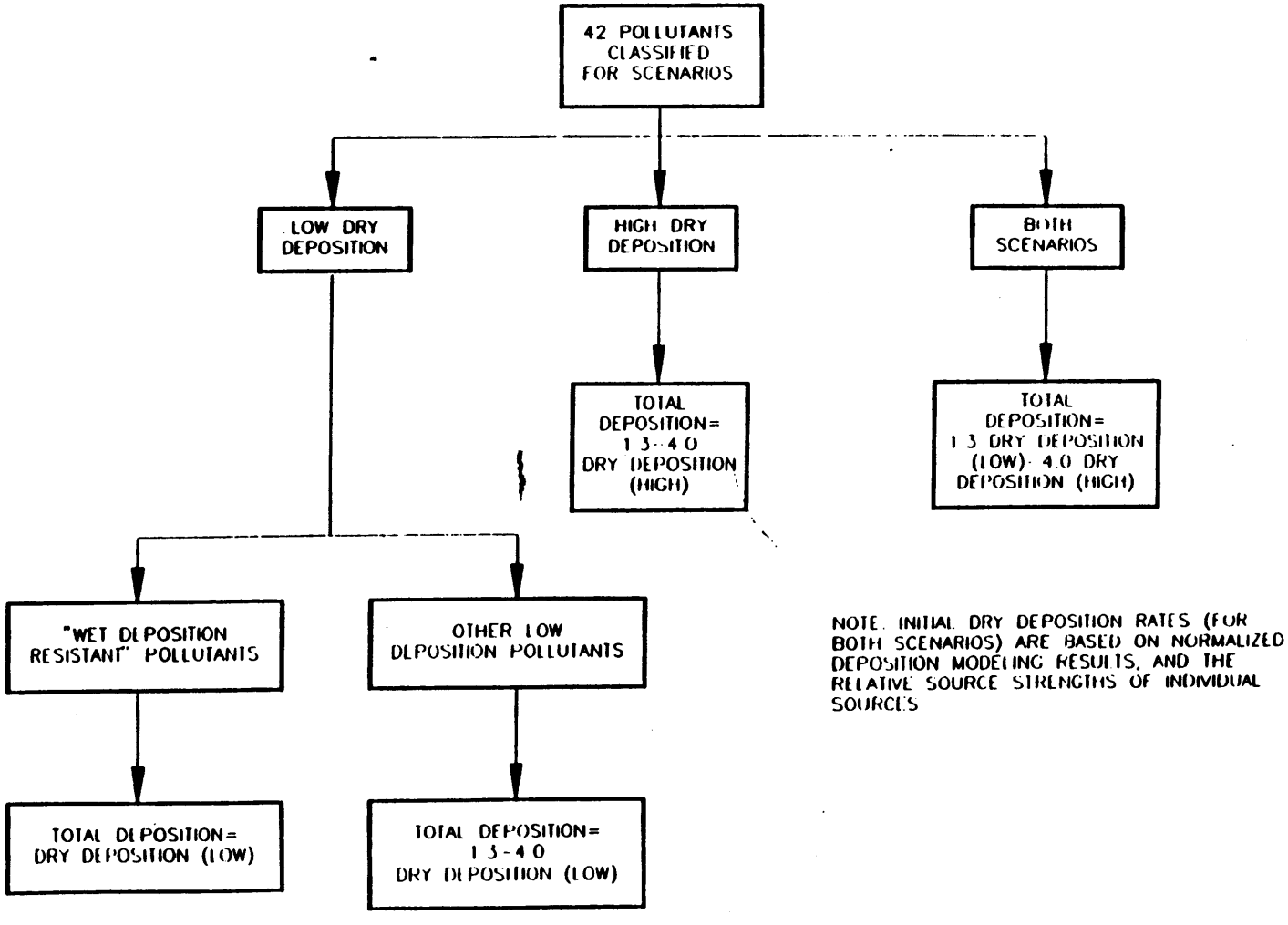


TABLE 5-2

SUMMARY OF ATMOSPHERIC DEPOSITION IN GREAT LAKES WATERWAYS IN THE STUDY AREA

Pollutant	Deposition Range (tons/year)*
Acrylonitrile	.05-0.2
Allyl chloride	.01 (dry only)
Arsenic	1-3
Asbestos	.6-1
Benzene	100-300
B(a)P	.4-1
Beryllium	.6-2
1,3 butadiene	20 (dry only)
Cadmium	.5-1
Carbon tetrachloride	.02 (dry only)
Chlordane	.03-.1
Chloroform	.01 (dry only)
Chromium	4-10
Chrysene	.4-1
Coke oven emissions	70-200
Diazinon	.1-.4
Dibutyl phthalate	.7-10
Dioxins	.0003-.0008
Epichlorohydrin	.08-.2
Ethylene dibromide	.4-1
Ethylene dichloride	1-4
Ethylene oxide	.04-.1
Fluoranthene	.5-2
Formaldehyde	3-9
Furans	.0003-.0008
Gasoline vapors	600-2000
Guthion	.3-.9
Heptachlor	.008-.02
Lead	10-40
Mercury	.2-.7
Methyl chrysene	.2-.6
Methylene chloride	4-10
Nickel	6-20
Parathion	.05-.1
PCBs	.007-.09
Perchloroethylene	30-90
Phenanthrene	.2-3
Selenium	.4-10
Styrene	10-200
Total PAHs	6-20
Trichloroethylene	20-50
Vinyl chloride	.6 (dry only)

*To one significant digit

DISCUSSION

Data Inputs

As mentioned above, it should be reiterated that the results in Table 5-2 are just for the 102 grid cells that border on major Great Lakes waterways in the Transboundary area. Other grid cells in the area will certainly receive deposition of one or more of the 42 toxic substances which are emitted in the area.

In many ways, this analysis is conservative. It is assumed that any substance which is deposited into a grid cell which touches a major Great Lakes waterway in fact runs off into that waterway. Though conservative, this assumption should be balanced out in part by deposition into grid cells within the Transboundary area (or even places outside the area) within the Great Lakes watershed which results in run-off contribution.

Use of ISCLT itself may be conservative. Some past studies (for example, Tesche et al., 1987) suggest that ISCLT does not always conserve mass and that ISCLT estimates can at times substantially over-estimate actual deposition rates. Recommendations to remedy such potential deficiencies have included suggestions for higher reflection coefficients than that normally recommended. While the reflection coefficients used may therefore overestimate short range deposition, it is not clear what impact the reflection coefficient assumptions would have on total regional deposition (which is the subject of this study). However, it is likely because of past studies with ISCLT that the deposition rates calculated are conservative.

Results

One way to judge the reasonableness of the results is to compare the deposition results with the emission results. As might be expected, those pollutants with higher emission totals also have higher deposition totals. This generalization of course is not uniformly true because of the differing deposition assumptions for different pollutants.

Though there was no analysis to determine total deposition in the entire Transboundary region to ensure that there were no "conservation of mass" anomalies, the results do seem to be reasonable. Deposition rates range from less than 1 percent of total

emissions to almost 30 percent. A significant portion of emissions should be available for deposition because prevailing winds usually vary from south to west, and a significant portion of the major Great Lakes waterways are downwind of the greatest concentration of emissions (in the core area). The modeling results appear to reflect such a phenomenon.

It should be noted that these results, while apparently reasonable, should be considered as a starting point for additional analysis. For particular pollutants of concern, more sophisticated modeling should be considered, using regional models developed specifically for deposition analysis. While the emission results are relatively comprehensive (see Chapter 4), much more can be done to evaluate and develop specific modeling assumptions. Factors to be considered include vapor/particle phase partitioning and precipitation scavenging ratios for specific substances. Priorities for this kind of analysis can be set on the basis of the importance of individual substances for Great Lakes water quality, the reported deposition ranges provided by this and other studies, and assessments of the significance of atmospheric deposition of specific substances into the Great Lakes versus other input routes.

REFERENCES

Abbott, D.C.; Harrison, R.B.; Tatton, J. O'G.; and Thomson, J., "Organochlorine Pesticides in the Atmospheric Environment," Nature, 208:1317 (1965).

American Conference of Governmental and Industrial Hygienists, "Threshold Limit Values and Biological Exposure Indices for 1987-1988," Cincinnati, OH, 1987.

Bidleman, Terry F., "Atmospheric Processes," Environmental Science and Technology; 22:361 (1988).

Bidleman, Terry F.; Billings, W. Neil; and Foreman, William T., "Vapor-Particle Partitioning of Semivolatile Organic Compounds: Estimates from Field Collections," Environmental Science and Technology, 20:1038 (1986).

Botts, Lee, "Toxic Fallout: The Invisible Great Lakes Problem," Great Lakes Waste and Pollution Review Magazine, 1:7 (June 1983).

California Air Resources Board, "Deposition Rate Calculations for Air Toxics Source Assessments," Appendix C.7, Air Toxics Assessment Manual, California Air Pollution Control Officers Association, Sacramento, CA, 1987.

Carey, Penny M., "Air Toxics Emissions from Motor Vehicles," EPA-AA-TSS-PA-86-5, Office of Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, MI, 1987.

Carhart, Bruce S.; Cornman Melinda K.; Koucky, Walter F.; and Opperman, Andrew J., "Refining Air Toxics Emission Inventories: A New Jersey Case Study," Paper No. 88-131.8, presented at 81st Annual Meeting of the Air Pollution Control Association, Dallas, TX, 1988.

Carhart, Bruce S.; and Walsh, Michael P., "Potential Contributions to Ambient Concentrations of Air Toxics by Mobile Sources," Paper No. 87-2.5, presented at the 80th Annual Meeting of the Air Pollution Control Association, New York, NY, June 1987.

Crockett, A.B., et al., "Pesticides in Soil," National Soils Monitoring Program, Pesticides Monitoring Journal, 8(2), (1974).

Eisenreich, Steven J.; Looney, Brian B.; and Thornton, J. David, "Airborne Organic Contaminants in the Great Lakes Ecosystem," Environmental Science and Technology, 15:30 (1981).

Green, Don W., Editor, Perry's Chemical Engineer's Handbook, McGraw-Hill Book Company, New York, NY, 1984.

Harrison, Paul R., "Atmospheric Deposition of Trace Elements," A Specialty Conference on Atmospheric Deposition, APCA Specialty Conference Proceedings, SP-49, Air Pollution Control Association, Pittsburgh, PA, 1982.

Howard, Philip H., Editor, "Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume I, Large Production and Priority Pollutants," Lewis Publishers, Chelsea, MI, 1989.

Howard, Philip H., Editor, "Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume II, Solvents," Lewis Publishers, Chelsea, MI, 1990.

Illinois Environmental Protection Agency, "The Southeast Chicago Study: An Assessment of Environmental Pollution and Public Health Impacts," IEPA/ENV/86-008, Environmental Programs, Springfield, IL, March 1986.

International Joint Commission, Science Advisory Board/Water Quality Board/International Air Quality Advisory Board, Summary Report of the Workshop on Great Lakes Atmospheric Deposition, held October 29-31, 1986 (Scarborough, Ontario), Windsor, Ontario, October 1987.

Journal of Great Lakes Research, 7(3):330-335, International Association of Great Lakes Research (1981).

Kelly, Thomas J.; Czuczwa, Jean M.; Sticksel, Philip R.; and Sverdrup, George M., "Input of Toxic Substances from the Atmosphere to Lake Erie," Ohio Air Quality Development Authority, Columbus, OH, 1989.

Lakes, James L. et al., "Origins of Polycyclic Aromatic Hydrocarbons in Estuarine Sediments," EPA 600/J-79-134, USEPA Research Laboratory, Narraganset, RI, July 1979.

McGee, Bill, "Survey of Pesticide Use in Ontario, 1983," Ontario Ministry of Agriculture and Food, Toronto, Ontario, September 1984.

McMahon, T.A., and Denison, P.J., "Empirical Atmospheric Deposition Parameters – A Survey," Atmospheric Environment, 13:571 (1979).

McVeety, Bruce D., and Hites, Ronald A., "Atmospheric Deposition of Polycyclic Aromatic Hydrocarbons to Water Surfaces: A Mass Balance Approach," Atmospheric Environment, 77:511 (1988).

Murphy, Thomas J.; Mullin, Michael D.; and Meyer, Joseph A., "Equilibration of Polychlorinated Biphenyls and Toxaphane With Air and Water" Environmental Science and Technology, 21(2) (1987).

Murphy, Thomas J.; Pokojowczyk, Jean C.; Mullin, Michael D., "Vapor Exchyange of PCBs with Lake Michigan: The Atmosphere as a Sink for PCBs," Physical Behavior of PCBs in the Great Lakes, Ann Arbor Science Publishers, Ann Arbor, MI, 1983.

National Research Council, "Polycyclic Aromatic Hydrocarbons: Evaluation of Sources and Effects," National Academy Press, Washington, DC, 1983.

New York Times, "Airborne Pollutants Held a Threat to Great Lakes," March 3, 1987.

Rice, Clifford P., "Non Acidic Deposition: Organics," A Specialty Conference on Atmospheric Deposition, APCA Specialty Conference Proceedings, SP-49, Air Pollution Control Association, Pittsburgh, PA, 1982.

Rose, A. Hugh, and Wayne, Lowell G., Ph.D., "Inventorying Pesticide Emissions," Paper No. 84-72.5, presented at the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, CA, June 1984.

Santodonato, Joseph, Ph.D., "The Carcinogenic Potential of Polycyclic Organic Matter Complex Mixtures From Various Emission Sources," Center for Chemical Hazard Assessment, Syracuse Research Corporation, prepared for USEPA/ORD, Carcinogen Assessment Group, March 24, 1984.

Scudlark, Joseph R., and Church, Thomas M., "The Atmospheric Deposition of Arsenic in Association with Acid Precipitation," Atmospheric Environment, 22:937 (1988).

Sehmel, George A., "Particle and Gas Dry Deposition: A Review," Atmospheric Environment, 14:983 (1980).

Strachan, William M.J.; and Steven J. Eisenreich, Mass Balancing of Toxic Chemicals in the Great Lakes, The Role of Atmospheric Deposition, International Joint Commission/Science Advisory Board/Water Quality Board/International Air Quality Advisory Board, Appendix I from Workshop on the Estimation of Atmospheric Loadings of Toxic Chemicals to the Great Lakes Basin (held October 1986), May 1988.

Summerhays, John, "Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southeast Chicago," Air and Radiation Division, Region V, USEPA, Chicago, IL, September 1989.

Summerhays, John, and Croke, Harriet, "Air Toxics Emission Inventory for the Southeast Chicago Area," Air and Radiation Branch, Region V, USEPA, Chicago, IL, July 1987.

Swackhamer, Deborah L.; McVeety, Bruce D.; and Hites, Ronald A., "Deposition and Evaporation of Polychlorobiphenyl Congeners to and from Siskiwit Lake, Isle Royale, Lake Superior," Environmental Science and Technology, 22:664 (1988).

Swackhamer, Deborah L., and Armstrong, David E., "Estimation of the Atmospheric and Non-atmospheric Contributions and Losses of Polychlorinated Biphenyls for Lake Michigan on the Basis of Sediment Records of Remote Lakes," Environmental Science and Technology, 20:879 (1988).

Tesche, T.W.; Kapahi, R.; Honrath, R.; and Dietrich, W., "Improved Dry Deposition Estimates for Air Toxics Risk Assessment," Paper No. 87-73B.1, presented at the 80th Annual Meeting of the Air Pollution Control Association, New York, NY, June 1987.

Thibodeaux, Louis J., Chemodynamics: Environmental Movement of Chemicals in Air, Water, and Soil, John Wiley & Sons, New York, NY, 1979.

USDA/ERS, "Outlook and Situation (Pesticides)" Washington, DC, October 1983.

USEPA/ECASO, "Research and Development, Drinking Water Criteria Document for Heptachlor, Heptachlor Epoxide, and Chlordane," EPA 600/X-84-1971, Cincinnati, OH, March 1985.

USEPA/GLNPO, "The IJC Menomonee River Watershed Study Atmospheric Chemistry of PCBs and PAHs," EPA 905/4-79-029-1, Great Lakes National Program Office, Chicago, IL, March 1980.

USEPA/GLNPO, "1987 Report on Great Lakes Water Quality: Report to the IJC," Great Lakes National Program Office, Chicago, IL, 1988a.

USEPA/GLNPO, "Five Year Program Strategy for Great Lakes National Program Office, FY 1989-1993," Great Lakes National Program Office, Chicago, IL, 1988b.

USEPA/OAQPS, "Industrial Process Profiles for Environmental Use, Chapter 10, The Plastics and Resins Processing Industry," EPA 600/2-85/086, July 1985.

USEPA/OAQPS, "Locating and Estimating Emissions from Sources of (Pollutant)," EPA 450/4-84-007, series a-p, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1985-1988.

USEPA/OAQPS, "Guideline on Air Quality Models (Revised)," EPA 450/2-78-027R, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1986a.

USEPA/OAQPS, "Industrial Source Complex (ISC) Dispersion Model User's Guide – Second Edition," EPA 450/4-86-005a and b, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1986b.

USEPA/OAQPS, "National Dioxin Study Tier 4-Combustion Sources, Project Summary Report," EPA 450/4-84-014g, Office of Air and Radiation, Research Triangle Park, NC, September 1987.

USEPA/OAQPS, "Air Emissions Species Manual, Volume 1, Volatile Organic Compound Species Profiles," Office of Air Quality Planning and Standards, Research Triangle Park, NC, April 1988a.

USEPA/OAQPS, "Air Emissions Species Manual, Volume 2, Particulate Matter Species Profiles," Office of Air Quality Planning and Standards, Research Triangle Park, NC, April 1988b.

USEPA/OAQPS, "Toxic Air Pollutant Emission Factors - A Compilation for Selected Air Toxic Compounds and Sources," Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 1988c.

USEPA/OAQPS, "Bases of Risk Assessment Inputs for Chromium Electroplating Operations," Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1988d.

USEPA/OAQPS, "Locating and Estimating Air Emissions from Municipal Waste Combustors," Draft Report submitted in response to Work Assignment No. 27, Contract No. 68-02-4392, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 1988e.

USEPA/OAQPS, "Analysis of Air Toxics Emissions, Exposures Cancer Risks, and Controllability in Five Urban Areas," EPA 450/2-89-012a, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1989a.

USEPA/OAQPS, "Estimating Air Toxics Emissions from Coal and Oil Combustion Sources," EPA 450/2-89-001, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1989b.

USEPA/OAQPS, "Review and Evaluation of Area Source Dispersion Algorithms for Emission Sources at Superfund Sites," EPA 450/4-89-020, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 1989c.

USEPA/OAR and OPPE, "The Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants," Office of Air and Radiation and Office of Policy, Planning, and Evaluation, Washington, DC, 1985.

USEPA/OHEA, "Polycyclic Organic Matter (POM) Source Profiles and Exposure, Final Report," Syracuse Research Corporation, Syracuse, NY, 1984.

USEPA/OPP, "Pesticide Fact Sheet, #107, Heptachlor," Office of Pesticides and Toxic Substances, Washington, DC, December 1986a.

USEPA/OPP, "Pesticide Fact Sheet, #108, Aldrin," Office of Pesticides and Toxic Substances, Washington, DC, December 1986b.

USEPA/OPP, "Pesticide Fact Sheet, #109, Chlordane," Office of Pesticides and Toxic Substances, Washington, DC, December 1986c.

USEPA/OPP, "Pesticide Fact Sheet, #111, Parathion," Office of Pesticides and Toxic Substances, Washington, DC, December 1986d.

USEPA/OPP, "Production, Distribution, Use and Environmental Impact Potential of Selected Pesticides, 1975," EPA 540/1-74-001, Office of Water and Hazardous Materials, Washington, DC, 1975.

USEPA/ORD, "The Degradation of Selected Pesticides in Soil: A Review of the Published Literature," EPA 600/9-77-022, Cincinnati, OH, 1977.

USEPA/ORD, "Criteria Pollutant Emission Factors for the 1985 NAPAP Emission Inventory," EPA 600/7-87-015, Office of Research and Development, Research Triangle Park, NC, 1987a.

USEPA/ORD, "Risk Assessment Guidelines of 1986," EPA 600/8-87-045, Office of Research and Development, Washington, DC, 1987b.

USEPA/OWRS, "An Exposure and Risk Assessment for Benzo(a)pyrene and other Polycyclic Aromatic Hydrocarbons, Volume 7, Summary," EPA 440/4-85-020, Washington, DC, 1982.

USEPA/OWRS, "An Exposure and Risk Assessment for Phthalate Esters," EPA 440/4-81-020, Washington, DC, May 1981.

U.S. Public Health Service/ATSDR, "Heptachlor/Heptachlor Epoxide, Toxicological Profile, Draft for Public Comment," USEO-428, November 1987.

Wade, David, Michigan Department of Agriculture, personal communication January 12, 1989.

Wallace, Dennis; Johnson, David; and Vaught, Charles, "Analysis of Potential Emissions of CDDs/CDFs From Wire Reclamation Incinerators in Illinois," October 1, 1987.

Weast, Robert C., Ph.D., Editor, CRC Handbook of Chemistry and Physics, Forty-eighth edition, The Chemical Rubber Company, Cleveland, OH, 1967.

Wolfe, H.R. et al., "Persistence of Parathion in Soil," Bulletin of Environmental Contamination and Toxicology, Vol. 10, No. 1 (1973).